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RELATING TO

THE ORISSA COAST CANAL.

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ORISSA COAST CANAL.

No. 14.

Note by Colonel F. T. Haig, R. E., Chief Engineer, Bengal, Irrigation Branch, on the probable cost and financial prospects of a High Level Canal connecting the Midnapore Canal with the Orissa High Level at Bhuddruck.

The line which this canal would follow from Bhuddruck to Balasore has been laid out, and the works have been estimated for in detail by Mr. Vertannes. His canal is designed of similar dimensions to those of the High Level between Bhuddruck and Cuttack, *viz.*, with a bottom width of 88 feet and a depth of 8 feet. The slope allowed is 1 inch per mile. The locks are all 150 feet by 20 feet in the chamber. The canal is to be taken across the Salundi by a weir, and is to be locked down into tide water in the Burrabullong, a little below the town of Balasore. The length is 50 miles, and the total fall 50 feet, which is overcome by five locks, inclusive of one which acts rather as a regulator placed half-way down the canal.

2. The estimated cost for works alone, including maintenance, is—

	R
Head works on the Salundi	7,03,627
Canal	32,37,612
Short branch canal to the town of Balasore	51,049
Drainage and protective works	3,61,571
Total Works	43,55,909

Inclusive of establishments at 25 per cent. and tools and plant at 6 per cent., but without any allowance for pensions and interest, the total amounts to R57,06,240, or considerably over a lakh of rupees per mile.

3. Mr. Vertannes has adopted rates higher than those at which works have been carried out in Cuttack, believing that there will be greater difficulty in getting labor along this part of the canal, as well as for other reasons. His rates are lower than in Midnapore, and rather higher than those assumed in Mr. Long's very carefully prepared estimates for 80 miles of a proposed extension of one of the High Level Canals on the Sone. His rate for earthwork in canal generally is about R3-4 per 1,000 cubic feet, and for rubble and brick masonry R25 per 100. These do not differ much from those on the 3rd Section of the High Level now under construction; the rate for earthwork on which is higher than Mr. Vertannes's, *viz.*, R3-7-6, while that for masonry is slightly lower, *viz.*, R22 to R22-8. On the whole I think the rates allowed may be considered as sufficient, and no more.

4. As regards designs, there may possibly be some room for saving, especially in the locks, which seems to be generally rather costly. The item "River and hill torrent works" is high, *viz.*, R14,50,000, for works on 50 miles of canal. In the Sone estimates above referred to, it is R15,70,000 for 80 miles of a canal of similar dimensions. But the rainfall in Orissa is heavier than in Behar, and as Mr. Vertannes took great pains to ascertain the actual flood discharges of the principal streams, I am not disposed to make any reduction in this item.

Under the head of "Regulators," the principal work is the Salundi weir, the estimated cost of which with its subsidiary works (but exclusive of head locks) is R6,62,000 for works only. This is so far in excess of any previous estimate that it may excite surprise; but I must say that assuming the maximum flood discharge of the river to be, as Mr. Vertannes appears to have shown (supposing all the present spill between the hills and Bhuddruck to be confined to the river channel by embankments), not less than 120,000 cubic feet per second, I am unable to see how the canal can be taken across the river at a less cost. Supposing, however, this could be done for even half the estimated amount, it would not very materially affect the cost of the canal.

5. On the whole, therefore, I think Mr. Vertannes's estimate must be accepted, *i. e.*, that a canal of the full section of 120 feet at top with a depth of 8 feet to connect the Orissa High Level Canal at Bhuddruck with the Burrabullong at Balasore would cost R43,55,000 for works only, or, inclusive of the usual percentage charges, R65,00,000,—or R1,30,000 per mile.

6. As a further test, however, comparison may be made with the cost of other canals of the same kind under similar conditions.

7. The cost of Section I of the Orissa High Level Canal has been R60,000 per mile for works, or, deducting three locks, about R55,000.

8. The cost of Section II has been R53,000 for works, or, deducting locks, about R45,000. Less drainage is crossed in this section than on the first.

9. The estimate for the Sone High Level extension comes to R40,00,000 for works, or R50,000 per mile, or, deducting locks, R43,500.

10. Mr. Vertannes's estimate for the canal comes to R32,37,000 + 3,61,000 = R35,98,000 for works, or R72,000 per mile. But we have to deduct R5,40,000 for locks, leaving for the canal alone, exclusive of navigation works, R30,60,000 = 61,000 per mile. Bearing in mind the differences in rates, and the altogether exceptional difficulty of disposing of the drainage in any canal traversing the line of country between Bhuddruck and Balasore, I think the above comparison is, on the whole, confirmatory of the correctness of Mr. Vertannes's estimate.

11. The next section of the canal is that between Balasore and the Midnapore Canal The summit level of this section was intended to be in the Suburnrekha, across which a weir was proposed to be made somewhere near Dantoon, and from which one canal was to be led off with a very gentle fall towards the Midnapore Canal with which it would connect about 10 miles west of Panchkoorah; the other canal was to follow a line generally parallel to the main road to Balasore, and to lock into the Burrabullong near the terminus of the corresponding canal from the south.

12. There would appear to be an unnecessary expense in thus making the canals both north and south of Balasore lock down into tide water, when they might be connected directly by an aqueduct over the Burrabullong higher up. Mr. Vertannes, however, says there are serious objections to the latter scheme from the shape of the ground, and that it would be as expensive as the other. Upon this point I must confess I am disposed to differ from Mr. Vertannes, and think that, if ever a canal be made on this line, the practicability and cost of a direct connection should at least be investigated.

13. The length of the canal from Balasore to the Midnapore Canal would be 84 miles. It may be divided into two sections: the first, south of the Suburnrekha, 34 miles long, and the second, north of that river, 50 miles long.

14. The first section would cross a very difficult country in respect of drainage. A number of hill streams fall into it, and discharge their waters principally over the whole face of the country, the channels being small and insufficient. Drainage works on this section would probably be as expensive as in the Bhuddruck-Balasore Canal. North of the Suburnrekha the difficulties of this kind are less, though still the canal would traverse the whole drainage of the country, and in its upper 20 miles many of the distributaries of the Midnapore Canal. There would apparently be little or no lockage in this 50 miles of canal. A lock at either end and one intermediate might be sufficient, as there would appear to be only a few feet difference of level between the proposed weir on the Suburnrekha and the Midnapore Canal at the point of junction. Between the Suburnrekha and Balasore River there would be some 50 feet of lockage.

15. In roughly estimating the cost of the whole 84 miles of canal, Colonel Gulliver, it seems, assumed a mileage rate of R75,000 for works only. Mr. Vertannes adopted this in his report upon the comparative merits of the High Level and Coast lines, and Colonel Stoddard expressed his concurrence.

16. I do not, however, think that this view is supported either by the estimate for the Bhuddruck-Balasore Section or by the actual cost of the other sections of the Orissa High Level, as above shown.

17. Exclusive of lockage, the highest cost per mile is R61,000; the lowest R45,000. It will probably be safe to take R50,000 per mile for the 50 miles north of the Suburnrekha and R60,000 for the 34 miles south; and if we add to this for lockage at the rate of

R6,000 per foot of lift, which, though below Mr. Vertannes's estimate, is much in excess of actuals either in Orissa or in the Sone, the estimate would then come out as follows :—

	R	R
Midnapore Canal to Suburnrekha, 50 miles at R50,000	25,00,000	
3 locks	1,80,000	
		26,80,000
Suburnrekha to Balasore, 34 miles, at R60,000	20,40,000	
50 feet lockage at R6,000	3,00,000	
		23,40,000
Weir on the Suburnrekha, say		3,00,000
Total for Works only		53,20,000
Add percentage charges, including interest at 50 per cent.		26,60,000
Total cost of 84 miles Canal		79,80,000

18. The estimated cost of the Bhuddruck-Balasore Section being R65,00,000, we have for the whole line from the Midnapore Canal to Bhuddruck a probable cost of R1,45,00,000 or $\frac{\text{R1,45,00,000}}{\text{134 miles}}$ = R1,08,000 per mile.

19. Now, no one for a moment supposes that Government would spend this amount upon the canal as a navigation only. It is at least double, more probably treble, the amount that a canal ought to cost in order to pay interest simply from navigation tolls, inclusive of those on the additional traffic which the construction of this link would bring on to existing lines. The question then arises what returns might be looked for in the way of irrigation. As regards the lands which the canal would command in the Midnapore District, this question has been fully discussed by Mr. Harrison, the Collector, after careful local inquiry by a Deputy Collector specially deputed for that purpose. It appears that in that District about 200,000 acres would be irrigable from the canal, supposing the water-supply to be sufficient, a point upon which our information is at present rather vague. Mr. Harrison sums up his remarks as follows :—

> "As regards the irrigation, it would of course be a splendid boon to the cultivators of the tract in question if the High Level extension could be carried through, but the prospect of its paying the increased cost is more than problematical. If the entire 200,000 acres of rice land (300 square miles) were irrigated at R2 per acre, the income would be R4,00,000 gross, or say 2½ lakhs net, after paying the maintenance expense of both departments; but a far more probable estimate is that the newly-irrigated area in this district would hardly ever get beyond 100,000 acres at R1-8 per acre, or a gross income of 1½ lakhs against a maintenance and collection expenditure of, say, 1 lakh. Of course there is a similar tract, more or less one-fourth as large, in the Balasore District on this side the Suburnrekha; but I must confess that for *both* districts on this side the river I would take the 100,000 acres at R1-8 as a sanguine estimate."

20. Mr. Harrison speaks with authority upon this point after some years' observation of the actual results of irrigation in his district, and his estimate is that for the country north of Balasore not more than $\frac{3}{5}$ths of the area actually commanded would be irrigated every year even with a water-rate of R1-8 only; indeed, he looks upon this as a sanguine estimate of the returns. Experience in Midnapore undoubtedly confirms his view.

21. Now, with such a small return as this, the question arises whether irrigation would pay for the cost of distribution alone, much less leave any surplus towards payment of the interest on the canal. This it is not difficult to calculate, the cost of distribution and drainage being now well known in Midnapore and Orissa. The calculation would then be as follows :—

		R
	Distributaries for 250,000 acres at R5-8	13,75,000
	Drainage at R1	2,50,000
	Total Capital cost	16,25,000
Annual charges—		
	Interest at 4½ per cent.	73,100
	Maintenance at as. 4 per acre	62,500
	Collection charges at 10 per cent.	13,500
	Total	1,49,100

or almost exactly the receipts from water-rates.

22. Thus the best result that could be hoped for would be that the irrigation would pay the cost of distributaries. It would leave nothing over as a set-off against the charges for the canal, which would thus have to depend solely upon navigation for its returns.

23. I cannot pursue a similar investigation for the irrigable area under the Bhuddruck-Balasore Canal. There is no doubt that water would be more in demand there. On the other hand, I fear that the manner in which the country is inundated at times by the hill streams would be a serious drawback to irrigation, or at least a source of greatly increased expense in distribution if these streams are to be effectually controlled. From what I myself saw of the country between Jellasore and Balasore along the line of the high road, I believe irrigation would be almost impracticable throughout much of it, from the utterly uncontrolled manner in which the floods sweep over it. The Suburnrekha also would have to be embanked, and the cost of this has not been included in the above estimates.

24. On the whole, it appears to me that, having regard to the actual water-rate which the people are willing to pay, the difficulties arising from the character of the drainage south of the Suburnrekha and the little demand there is for water in Midnapore, to say nothing of doubts as to the water-supply actually available, we could hardly reckon on irrigation in the Midnapore and Balasore districts yielding higher returns than would pay the interest and cost of maintenance of the distributaries. If this view be correct, it is evident that irrigation must be set aside as an element in the question of the profits from any line of canal intended to connect the Hooghly with the Orissa Canal and river system. Navigation is apparently the only source of revenue to which we can look; and, if so, the High Level line discussed in this note stands, I fear, condemned as financially impracticable.

25. I add a few general considerations as to the prospects of traffic upon this line, as compared with a coast line of canal. It is evident, I think, at starting that the canal would have very little local traffic between Balasore and the Midnapore Canal. It would probably attract the traffic now carried on by sea and road between the town of Balasore and Calcutta, but it would receive little from the country between Balasore and the Midnapore Canal. That canal with its feeder the navigable distributary to Narainghur, the Kaliaghye, and the Hidgellee canals, practically provide for all the export and import traffic of the country north of the Suburnrekha, so that the 50 miles of High Level Canal north of that river would have little or no local traffic at all. Rice, for instance, from any point on the Jellasore and Baliaghye road, or in the country south of that road, could be taken to Calcutta *viâ* Hidgellee with only 27 miles of canal carriage and tolls, all the rest of the navigation being river. *Viâ* the High Level, it would have to pay tolls on 70 miles of canal. There can be no doubt as to which route it would prefer.

26. South of Balasore the High Level to Bhuddruck would be more favourably aligned for local traffic than a low line along the coast. But it is evident that if the existing High Level is to be the main line of traffic between the Cuttack Delta and Calcutta, it must have some other navigable connection with the estuaries of the Orissa rivers and the country on their banks, besides the Kendrapara Canal; otherwise, it will always compete at a disadvantage with the sea line. It runs along the upper margin of the delta, is skirted by a poor jungly country on the west, and is at the furthest possible distance from the centres of the most productive parts of the delta. The surplus produce of the deltas of all the three rivers tends naturally coastwise *viâ* the navigable estuaries and tidal creeks, and will more readily flow into a canal connecting these directly with Calcutta than into one which it can only reach by some 20 miles of land carriage, unless some additional lines of canal, such as the proposed Jajpore and Chandbali lines are made, of which there is now not the remotest prospect. For this reason I look upon a navigable connection between the present High Level at Bhuddruck and the Metai as much more necessary to the success of a High Level line to Balasore than to that of a low level, for the whole of the tidal traffic of the delta would flow readily into the latter in spite of the undoubted objections to the present entrance to the Metai pointed out by Mr. Walker. A Low Level Canal connecting the Burrabullong at Balasore with the Metai could do without the projected link between the head of the Metai and Bhuddruck. The High Level could not.

27. There is no doubt that a very much cheaper High Level Canal could be designed to connect Bhuddruck with Balasore than that planned by Mr. Vertannes, if irrigation be given up, and it would be the preferable line of the two, supposing it to have a connecting link with the tidal creeks and rivers of the delta. But it must be borne in mind in considering Mr. Vertannes's project for a Coast Canal, and comparing it with the alternative High Level, that it is mere waste of time to discuss *any* projects, large or small, of which it cannot be shown

conclusively by reference to actual facts and statistics that they will yield a return sufficient to pay the interest within a reasonable time. I notice in one or two recent papers a tendency to fall back upon a compulsory rate when the prospects of direct returns from voluntary irrigation from any projected canal are poor, and to supplement this argument by general considerations as to the duty of Government to develope the resources. It will be much better to assume that the Government is fully alive to its duty in this respect, and to design all projects only on such a scale, however humble, as we can show to be directly remunerative without resort to untried fiscal experiments, which, however applicable to existing schemes, may possibly not be considered to afford a proper financial basis for future undertakings of the same kind.

F. T. HAIG, *Colonel, R.E.,*
Chief Engr., Bengal, Irrign. Branch.

The 5th October 1877.

Note by Colonel F. T. Haig, R. E., Chief Engineer, Bengal, Irrigation Branch, on the proposed Orissa Coast Canal.

The proposal to connect Calcutta and the Hooghly with Orissa by canal is as old as the time of the Northern India Canal and Irrigation Company. The Chief Engineer, Colonel Rendall, had two projects in view with this object, *viz.*,—

1st.—A High Level Canal connecting the Mahanuddy, Brahminee and Byturnee, and which was to be carried with scarcely any fall on to Bhuddruck and Balasore, and thence *viâ* Jellasore to the Midnapore Canal, which it was to join a few miles west of Panchkoorah. This canal was to be fed from the rivers named as well as from the Suburnrekha, and was to irrigate along its whole length.

2nd.—A Low Level Canal to be taken along the coast from the head of the Metai Creek, 16 miles east of Bhuddruck, past Balasore, and through Hidgellee to the Russulpore River, where it was to connect with the Hidgellee Tidal Canal.

2. The second project was, I believe, intended to be merely supplementary to the first, and to provide a navigation which might be opened much sooner, and at a very much less cost than the High Level Canal, and which it was hoped would always be of use in the event of any failure of supply or closure from other causes on the upper line.

3. Neither project was fully worked out in the time of the Company, and both fell for a time into abeyance during the depression which followed the gradual and unwelcome discovery of the true character, financially, of the Orissa scheme. Within the last three years, however, both projects have been most fully and exhaustively investigated by Mr. Vertannes, one of our most competent and experienced Engineers, and the results are set forth in a series of elaborate reports, the first of which, on the proposed High Level Canal, I reviewed in a recent note. It will be well, before proceeding further, briefly to recapitulate the conclusions in respect to this particular project to which these inquiries have led.

4. The High Level Canal, then, would have a total length of 134 miles, and would cost R1,45,00,000, or R1,08,000 per mile. This amount includes no provision for distributaries. The cost of these, if the canal were to irrigate, would be in addition, and would, according to the best estimate that can now be made with the experience of several years' irrigation in the Midnapore District, only just be re-paid by the receipts from water-rates. The canal itself would thus be dependent for its returns upon navigation tolls only, and there is no prospect whatever of these ever amounting to such a sum as would cover the charge for interest and working expenses. For details, reference may be made to my note above referred to. The High Level scheme has, therefore, been definitely abandoned.

5. The need, however, of direct inland water communication with the Orissa rivers and canals remains the same, and if experience has shewn that the anticipations of the original

projectors of the Orissa works in regard to the revenue from irrigation must be largely abated, it equally points to the conclusion that the returns from navigation on all canals in Lower Bengal are likely to be much in excess of what was at first expected. As soon, therefore, as the results of the investigation of the High Level project became apparent, instructions were issued to Mr. Vertannes to design a canal on the Low Level line within such limits as to cost as there was reason to believe would be remunerative. He was told that the cost per mile, everything included, must not exceed R35,000. Taking as a basis of calculation the average toll collections on the Hidgellee Canal, *viz.*, R1,380 per mile, and assuming a rate of R500 per mile for working expenses, it was estimated that with the cost as above mentioned, there might be for some years an annual deficit of R895 per mile; but that this might be covered by the returns from the increased traffic which the new canal would bring on to the existing Hidgellee and Orissa canals. Mr. Vertannes was also ordered to report fully upon the existing and prospective traffic between Orissa and the Hooghly, and was cautioned to confine himself strictly to facts and figures verified by reference to the Collector's records and such other reliable sources of information as might be available. As he had already submitted detailed plans and estimates for a much more expensive class of canal, abstracts of approximate costs based upon the former estimates were all that were now required for the works which he had to propose.

6. The estimates thus called for, both of cost of works and of traffic, he submitted some months ago. His traffic report was then sent to the Commissioner and to the Collectors of Midnapore and Balasore for opinion. The reports of these officers, which are upon the whole strongly confirmatory of the correctness of Mr. Vertannes's estimate, are attached to this note. Mr. Norman, the Collector of Balasore's report is particularly full, and affords as complete a *resumé* of the whole question as can be desired by any person not compelled to go much into details. His mastery of the subject and thorough knowledge of his district render his opinions particularly valuable. I have now to state the result of these investigations.

7. The proposed canal is to start from the Russulpore River nearly opposite the southern terminus of the present Tidal Canal, and to follow a tolerably direct line thence to the Suburnrekha River and the Burrabullong, about 5 miles south of the town of Balasore. From this point it will again be carried along the coast to tidal water in the Metai. It may be conveniently divided into three sections, the lengths and cost of which according to Mr. Vertannes's estimate are as follows :—

	Length.	Cost.
	Miles.	R
Section I.—From the Russulpore to the Suburnrekha . .	30	7,55,000
„ II.—From the Suburnrekha to the Burrabullong . .	23½	9,79,000
„ III.—From the Burrabullong to the Metai . . .	37½	9,28,000
Total .	91	26,62,000

8. The dimensions assumed in this estimate are, for the canal, a bottom width of 40 feet with a minimum depth of 6 feet, slopes 1½ to 1; for the locks, a length of 100 feet in the chamber, and width of 200 feet. The restrictions in regard to cost imposed on Mr. Vertannes induced him (with my approval) to limit the dimensions as above stated. But after a full discussion of the whole subject with him, and a review of the traffic statistics, which are more promising than I expected, I am inclined to recommend an increase in depth in canal, and in the length of the lock chambers, and depth below tide level of their floors. Mr. Vertannes has planned all his locks with their lower sills at low-water level spring tides. This might occasion detention at times, which, though of no consequence to ordinary boats, would be unfavourable to steam traffic. I think the sills might be placed 2 feet lower. The length of 100 feet in the lock chamber is the same as that in the six locks in the Kendrapara Canal by which the proposed canal would connect with Cuttack, and the same as that of one out of the four existing locks in the Hidgellee Tidal Canal. But the great bulk of the Coast Canal traffic, both in passengers and goods, will not be with the town of Cuttack, but with the tidal creeks and estuaries of the Orissa rivers, and locks of 150 feet in length will be better adapted to it.

9. With regard to the canal, as it will be fed by the tides, it may be well, in anticipation of a large traffic, to give it a depth which will allow for a greater range of level during the tidal intervals. I propose, therefore, to give it a minimum depth of 7 feet. This depth it will have for only three months of the year, *viz.*, 15th November to 15th February; from

15th February to 15th June the southerly winds cause higher tides, and during the monsoon months the rains will raise the level still higher. Thus, the depth will be—

	As designed by Mr. Vertannes. Feet.	As now proposed. Feet.
15th November to 15th February	6	7
15th February to 15th June	7	8
15th June to 15th November	8	9

10. One other alteration has been suggested, *viz.*, the suppression of the two locks proposed between the Panchpara River and the Burrabullong, and the substitution of an open cut in this range of canal, which is only 6 miles in length. This, if it should be found practicable, would effect a large saving.

11. Taking this saving into account, Mr. Vertannes estimates that the canal, with the increased dimensions now proposed, may easily be made for R30,00,000 instead of R26,62,000 as in his original estimate. I quite think so myself. At the same time, in discussing the question whether it would prove a directly remunerative undertaking, I prefer to take an outside estimate, the more so, because the traffic returns show that the revenue from tolls alone will be amply sufficient to cover the interest on a liberal outlay. I therefore add 10 per cent. to Mr. Vertannes's estimate, and shall assume for the purposes of this note that the canal will cost 33 lakhs, which for 91 miles, is at the rate of R36,200 per mile.

12. It is necessary here to notice two objections which have been urged to the construction of a canal, as proposed, along the coast: (1) the difficulty of providing for the drainage; and (2) the effects of cyclones. The first is a difficulty which besets a canal carried on any level, high or low, through this part of Orissa. The streams soon after leaving the hills spread out in numerous small channels over the plains, and in many places lose all trace of a channel, and simply flow over the whole face of the country. The flood discharge of these streams is also, from the proximity of the hills, heavy. A canal crossing them on a high level must therefore be taken over them by numerous openings, and this is one reason for the high cost of the upper line. But a peculiar formation in the land gives a low level line an advantage. The slope of the country, which is rapid from the hills, suddenly falls to almost level within a few miles of the sea, and here the flood waters spread over a wide area and discharge by numerous small outlets into the sea. It is through this tract that the proposed canal is to be taken. The water level in it will be kept generally below ground, and the floods allowed to flow over it; special means of inlet and outlet being provided. The beds of the streams in this part of their course contain no sand, this and the heavier particles of silt having been deposited higher up, so that there is no fear of the canal being blocked up by such deposits. A catch drain to intercept any matter of this kind will also be provided in some parts of the line on the upper side of the canal.

13. With regard to cyclones, there is no doubt that the part of the coast along which the canal would run for a length of 40 miles, *viz.*, from about 10 miles north-east of Balasore to the Metai, is liable to be swept for a certain distance inland by storm-waves. Above the point mentioned, and through Hidgellee, the sea dyke and the sand-hills prevent the wave rolling over the country, but it can still ascend the rivers, though with diminished height and violence. It did so during the cyclone of October 1874; passed over the lock-gates of the southern half (18 miles in length) of the Hidgellee Canal, and traversed the canal from end to end; but the effects were insignificant. The injuries done to the works were repaired at a cost of R248 only. This part of the canal having its water level at a height of some feet above ground is much more liable to injury from such a wave than the proposed canal in which the water level would either be below ground, or, if above it, only at the general level of the drainage waters of the surrounding country. Yet the cyclone did it little or no damage. Thus 76 miles out of the whole 128 miles from the Hooghly terminus of the present canal to the Metai will be virtually protected from injury by cyclones. In the remaining 52 miles the canal would, during a cyclone, be simply a submerged trench in a vast lake of water, and over this the wave might travel with little or no injurious effect. The injury to a High Level Canal would be far greater from the torrents of rain which accompany a cyclone, and which would bring down floods which no masonry works constructed for ordinary rainfall could discharge. This was illustrated in the case of the Midnapore Canal in 1874, which was extensively breached, flooding large tracts of country, by the same cyclone which did only R248 worth of damage to the coast line. No doubt a certain amount of damage would be done by a storm-wave, and it is proper to take this into account in calculating the cost of maintenance; but I do not consider that this would be such a serious item of expense as to afford any valid reason for rejecting Mr. Vertannes's project.

14. The following statement shows the estimated cost of each section of the proposed canal in more detail than I have already given :—

Name of proposed Canals.	Length of proposed Canals.	DIRECT CHARGES.				INDIRECT CHARGES.				Total of direct and indirect charges.
		Works.	Establishment at 20 per cent.	Tools and plant at 3 per cent.	Total of direct charges.	Interest for 1½ years at 4½ per cent.	Pension at 25 per cent. on total cost of establishment.	Capitalization of land revenue.	Total of indirect charges.	
	Miles.	R	R	R	R	R	R	R	R	R
Range No. III	30	5,38,000	107,600	16,140	6,61,740	44,667	26,450	22,000	93,567	7,55,307
" " IV	23½	7,09,000	1,41,800	21,270	8,72,070	59,865	35,450	11,400	1,06,715	9,78,785
" " V	37½	6,65,000	1,33,000	19,950	8,17,950	55,211	33,250	21,645	1,10,106	9,28,056
Total .	91	19,12,000	3,82,400	57,360	23,51,760	1,59,743	95,600	55,045	3,10,388	26,62,148

15. It will be observed that establishments are calculated at 20 per cent. and tools and plant at 3 per cent., instead of the usual percentages of 25 and 6. As the greater part of the expenditure will be on earthwork, these percentages should be sufficient, especially as a good deal of plant is available for transfer from the Orissa and Midnapore works. If so, I presume that, now that the Local Government has become responsible for the interest charges on such works, the standing rule which requires that the higher percentages shall be charged indiscriminately in the case of all extraordinary works will not be enforced. The difference would amount to about R1,50,000; in other words, the total cost of the line would be 31½ instead of 30 lakhs. Mr. Vertannes has had such large experience, especially in that part of the country, having carried out the greater part of the works of the Hidgellee Canal, that I think his rates and estimates generally may be relied upon as sufficient. The project has been revised again and again, and has been sifted in every possible way. Nevertheless, as already said, I prefer to assume a somewhat higher figure.

16. I take, then, for my present purpose, the probable cost of a canal to connect the present Hidgellee Canal with tidal water in the Metai Creek at Rs. 33 lakhs. These, it seems to me, are the proper limits of the project.

17. Mr. Vertannes has included in his estimates one for a canal to connect the estuary of the Brahminee, into which the Metai falls, with the present Gobri Canal, a navigable branch of the Kendrapara Canal, and has also discussed and estimated for another line to connect the existing High Level Canal at Bhuddruck with the Metai. Now, no doubt a navigable connection with the town of Cuttack is desirable, perhaps even necessary, to the completeness of the scheme; but if it is to be made *viâ* the Gobri the works properly form a part of the Orissa Irrigation project, and not of the one under discussion.

18. Through some oversight, when the revised estimates for the Orissa scheme were submitted to the Secretary of State for sanction, no provision was made for carrying the Gobri line down to tide water in the Brahminee, without which the canal is nearly useless, for, as it is now, it terminates in a tidal river leading down to False Point in one direction, and in the other into the Brahminee, but closed at its head by a shoal for three-fourths of the year. As the sole object of the Gobri Canal was to give Cuttack direct communication with Chandbali, it is sufficiently evident that any further works that may be required for that purpose, such as the proposed extensionn down to tide water at Hunsooa on the Brahminee, should form part of the Orissa scheme, and as far as possible should be provided for by a re-distribution of the sanctioned outlay on other works. I think that possibly a lakh of rupees might, at any rate, be found for the purpose from savings on the 3rd section of the High Level Canal, and this would be about two-fifths of the sum required.

19. But Cuttack has already canal communication with tide water at Marshaghai on the Kendrapara Canal, and will shortly, on the completion of the extension of that canal to the Jumboo Creek at False Point, have connection at a second point. Now, the estuaries and tidal creeks of Orissa generally are navigable for distances of 20 to 30 miles inland, and a glance at the map will show what a large proportion of the whole of the deltas is thus accessible. The communication between estuary and estuary is generally bad, the connecting creeks being often navigable only at high water or half tide, but is capable of improvement and extension at a surprisingly low cost. I have before me an estimate lately submitted by Mr. Walker, the Superintending Engineer of Orissa, to the Collector of Cuttack, of the cost of "improving certain creeks in the district of Cuttack so as to make them navigable by country boats at all times of the tide." It amounts to R32,450 for all works required

between the Metai and the Daib, a distance measured in a direct line on the map of nearly 70 miles. Mr. Walker, whose sound judgment and intimate knowledge of the localities renders his opinion especially valuable, adds :—" If funds can be found for the works, I shall write to the Collectors of Balasore and Pooree with the view of ascertaining whether they can in like manner provide funds for improving the Metai and Moogranee and Noona channels which lie in their respective districts, and the regulating of which would at once give a line of tidal communication 100 miles in length (excluding sinuosities), stretching from Rokanaidpore on the Metai in the Balasore District to Telicood on the Kadooa in the Pooree District" (a point apparently about 16 miles from the town of Pooree). All this, it would seem, may be done at an outlay of about R 50,000 or R 60,000, which Mr. Walker proposes to allot from the Road-Cess Funds.

20. Now, if the inter-tidal connections thus proposed are made, not only will the town of Cuttack, but which is of far greater importance, at least three-fourths of the whole area of the Mahanuddy, Brahminee and Byturnee deltas will have direct water communication with the Metai, and, if the canal now under discussion be carried out, with Calcutta; and as Mr. Walker's proposals are financially within the means of the District Road Committees, and can be carried into effect at their expense, I hold that the only part of the whole line of water communication which should be treated as an imperial work is the proposed canal from the Metai to the Russulpore. I therefore set aside the question of the best mode and probable cost of continuing the navigation up to the town of Cuttack. That is either a question for the local authorities to consider, or it belongs to the Orissa Irrigation scheme. It does not properly enter into discussion of the present scheme at all.

21. One other question it is necessary to notice in connection with this part of the subject, *viz.*, whether the existing High Level should be connected with the proposed canal at the Metai. The constructors of the canal and local authorities would appear to be in favor of this project. The High Level has been a favorite line. It has cost a large sum of money, and there is something incongruous in the idea of its terminating abortively in a paddy field; but the connecting link, which would be 16 miles long, would cost at least 10 lakhs, as much as the whole section of canal from the Metai to Balasore. It would, I fear, bring little traffic to the coast line, for the first range between the Mahanuddy and Brahminee skirts a wild jungly country on one side, and waters a very narrow strip on the other, and would, as well as Ranges 2 and 3, have very trifling local traffic. All that would go down the proposed link would be the traffic from the Upper Brahminee and from Cuttack, but both of these can be provided for *viâ* Range 1 of the High Level and the Kendrapara Canal, though this would be a more circuitous route. I cannot, therefore, look upon this link between the High Level and the Metai as necessary. It is about the last extension I should recommend, and I do not believe it could possibly pay the interest on its cost either directly or indirectly. There would be no irrigation from it.

22. I proceed, in the next place, to give some particulars of the existing export and import trade of Orissa, which it is expected will be so largely affected by the proposed canal. With the exception of a portion of the exports and imports from Balasore, which find their way to Calcutta *viâ* the Hidgellee Canal, the traffic is almost wholly by sea, and is carried on (1) with Calcutta, and (2) with the Mauritius and South Indian ports. The following statement shows the proportions in which it is distributed between these two heads :—

Total imports by Sea.

YEARS.	Balasore and minor ports in that District.	Chandbali.	False Point.	Total.
	R	R	R	R
1873-74	4,86,000	12,27,000	11 33,000	
1874-75	6,17,000	20,09,000	9,05,000	
1875-76	4,42,000	16,30,000	13,80,000	
1876-77	4,98,000	29,37,000*	11,88,000	*Of this R 12,39,000 were treasure.
Average . . .	4,08,000	15,60,000	9,21,000	28,89,000
	Total Exports by Sea.			
1873-74	8,62,000	7,69,000	8,58,000	
1874-75	6,29,000	15,09,000	11,24,000	
1875-76	5,27,000	11,72,000	8,99,000	
1876-77	17,24,000	22,97,000	23,63,000	
Average . . .	9,35,000	14,37,000	13.11,000	36,83,000
	Average total annual Imports and Exports.			
	13,43,000	29,27,000	22,32,000	65,72,000

Of this total, the trade with Calcutta is approximately as follows :—

	Balasore and minor ports.	Chandbali.	False Point.	Total.
	R	R	R	R
Imports	4,08,000	15,60,000	9,21,000	28,89,000
Exports	6,50,000	10,00,000	6,00,000	22,50,000
Total .	10,58,000	25,60,000	15,21,000	51,39,000

23. It thus appears that 52 lakhs out of a total of 65 lakhs, or in other words $\frac{5}{6}$ths of the whole import and export trade, is with Calcutta. The imports are wholly from Calcutta, and $\frac{22}{36}$ths or about two-thirds of the exports to the same place. In ordinary years the proportion would be still higher, the exports to southern ports in the last year in the table 1876-77, having been abnormally large in consequence of the famine. The difficulties of export in ocean-going ships or steamers are in fact so great, that despite the expectations that have been raised about False Point, it would seem that Calcutta must still remain the principal port for all the foreign trade of Orissa.

24. The following description of the Orissa port is taken from the report of the Collector of Balasore :—

> "The ports of Orissa are the seven Balasore ports, the port of False Point in Cuttack, and the open roadstead of Pooree, where the surf is almost prohibitive to landing and shipping operations. For a general account of the Balasore ports, I solicit reference to an article written by me, which will be found at page 265 of the Statistical Reporter for April 1876. In that article the ruinous effect of the silt upon all the port entrances has been noticed, and since that article was written no improvement has manifested itself. According to the latest surveys, the Dhamra bar leading to Chandbali has only six or seven feet of water on it at low tide, with a rise of ten feet at high water ; the Balasore bar has but one foot at low water, with a rise of thirteen feet at high water springs ; and the other ports are quite inaccessible to ships of any considerable burthen. During the north-east monsoon of 1876-77 a considerable number of English and foreign ships visited Balasore for the purpose of carrying cargoes of rice to Bombay and Madras, but they were unable to approach nearer than the buoy in the Balasore roads, which is no less than twenty-three miles distant from the port and town, and where they were loaded with great delay and expence by means of cargo boats, which are unable, owing to the distance, to make more than one trip in the twenty-four hours. Recently several disastrous accidents have occurred in attempting to take out to sea from the port of Dhamra (which includes Chandbali) ships laden to the depth of 17, 18 and 19 feet. As to False Point, it is situated in dense jungle, 70 miles from Cuttack ; the anchorage is extremely difficult of approach by cargo boats ; and I have been informed by the late Captain Harris, Conservator of the Orissa ports, who had an experience of the place extending over at least eleven yeai , that the harbour is rapidly and surely deteriorating, so that in a few years vessels of any size will be unable to enter it. It is only during the north-east monsoon that the capabilities of the Orissa ports, such as they are, can be fully utilized. For one-half of the year the Orissa coast is a lee-shore and very difficult of access by sailing vessels ; to native sloops the difficulties are quite prohibitive ; accordingly, sloop owners are in habit of berthing their sloops in the mud either in the Hooghly or the Balasore River, during one-half the year."

25. It would be more correct to say that the Orissa coast is a lee-shore for two-thirds of the year. The whole of the export or import trade of Balasore with Calcutta is carried on between 15th November and 15th March in native sloops, the largest of them only 150 tons burthen, and the annual losses in men and sloops are reckoned by the native merchants at 5 per cent., the insurance charges being proportionately heavy. It is only in times of such extraordinary prices as those of the last year that anything larger than a native sloop would venture out of Chandbali. False Point is certainly not improving: it is, according to latest accounts, deteriorating. The British India Steam Navigation steamers are not able now to enter the harbour, but anchor outside just off the point, and access to them is often dangerous, even for well-manned passenger boats; while no cargo boat, however well-built and rigged, can be taken alongside without steam. No native boat dare venture out to the anchorage, and the export trade, such as it is, is practically a monopoly in the hands of one or two firms of small capital. The steady inward trend of the ever-advancing-sand spit which shelters the anchorages is also a constant source of anxiety, threatening as it does the ultimate extinction of the harbour, and this can only be prevented, if prevented at all by an outlay the limits of which it is not easy to foresee. The difficulties in the case of sailing ships are still greater. Not one in ten could even enter the harbour. To load they must lie outside, and that is only practicable during some four or five months of the year, and even then with risk of destruction in case of a gale. I refer now to ordinary ocean-going ships such as those frequenting the port of Calcutta.

26. The following statement of the exports of rice and paddy, which constitute the great bulk of the exports of Orissa, will afford an idea of the comparative importance of False Point as a port:—

	Exports from all Balasore ports, Chandbali included.	Exports from False Point.
	Cwt.	Cwt.
1873-74	652,000	199,000
1874-75	762,000	151,000
1875-76	394,000	41,000
1876-77	1,111,000	367,000

27. In 1876-77, in spite of the bar at the mouth of the Dhamra, the exports of rice and paddy from Chandbali to Calcutta were 283,000 cwt., and to South Indian ports about 650,000 cwt., not far short of double the *total* exports from False Point. In the previous year, Chandbali exported of rice and paddy 190,000 cwt. to Calcutta alone, False Point, 41,000 cwt. to Calcutta and all other ports.

28. I give these figures merely to show that Orissa is as yet without any port suited to anything beyond the mere petty coasting trade. Even under the stimulus of the immense prices of last year, the total exports of rice from False Point were only 18,000 tons—a quantity perfectly insignificant in comparison with the resources of the district.

29. The trade of Cuttack is going more and more to Chandbali, but this port has the same disadvantages as False Point for any other than coasting traffic. It has, in fact, no other traffic, as no sea-going ships can safely enter the Dhamra. Chandbali has now two steamers running between it and Calcutta, making each a trip every week. The passenger traffic is large, having grown to 68,000 persons in 1876-77, and the growth of the goods traffic under the influence of keen competition has been rapid also. Still the price of export to Calcutta by this route, even at the present exceptionally low rates, is much beyond what is required, and double which it might be by canal. Further, it is important to notice that, however largely the trade of Chandbali may be in excess of that of False Point, the aggregate of both is small in comparison of the area contributing it. Thus the total exports to all quarters from these two ports in 1876-77 were 1,000,000 cwt., or 50,000 tons. The area of rich delta country alone from whence this was derived, to say nothing of the Gurjats, was at least 4,000 square miles. In the same year there were exported from Hidgellee *viâ* the short Tidal Canal, which taps a tract not above 1,500 square miles in extent, about 70,000 tons of rice and paddy. At the same rate the exports from the two Cuttack ports ought to have been 187,000 tons, or nearly four times what they actually were. There can be but one reason for this—the want of cheap carriage to a good and safe port.

30. It has been held by some that False Point is the proper port for Cuttack, and that it must be a mistake to lay out money on a Coast Canal to the Hooghly, as rice will never follow that line to an expensive port like Calcutta when it has a cheap one close at hand. Without going into the question of the capabilities of False Point as a harbour, it is enough to reply that if it should ever take the place of Calcutta for the exports of Orissa, the need of a Coast Canal would remain just the same. Balasore, for instance, lies about half-way between Cuttack and False Point, and if export were decidedly cheaper from the latter than from the former port, its rice would certainly gravitate thither, supposing there to be a canal, rather than as it does now to Calcutta. A continuous Coast Canal from the Chilka Lake to the Hooghly is evidently the first essential to cheap distribution and exports wherever the ports may be. It must ever remain the great channel of trade, and though the directions in which this may flow will vary with the points of outlet, the quantities will remain much the same, and would be increased rather than diminished if False Point should ever prove a cheaper port than the Hooghly.

31. In this connection, it may be well to advert to the importance of such a coast line of canal in times like those of the past two years when vast quantities of grain are set in motion. No sea-route could supply the place of a canal. The Dhamra can only be entered by steamers of limited draft, and the number of these cannot be increased on an emergency, except at such an enormous expense as the Government only could bear. False Point is at a similar disadvantage, and Balasore worse off still. But were a canal in existence, thousands of boats would swarm to it from all parts of Bengal were the demand to arise, and such a traffic as famine only could create would be accommodated without any expense or interference on the part of Government, and with the sole effect of doubling or trebling the navigation tolls as in Hidgellee and Midnapore last year.

32. As I have spoken of the Chilka Lake as a possible terminus for the coast line, I may mention that this lake is connected by canal with Ganjam, so that the traffic basin of the proposed canal may ultimately be very much larger than Mr. Vertannes has assumed in his calculation.

33. Turning now to the question of the cost of carriage by the proposed canal as compared with that by existing routes, I find the cost stated by Mr. Vertannes as follows :—

Names of Stations.	PRESENT RATES OF FREIGHT.				Probable rates by the proposed canals.	REMARKS.
	By land *viâ* Midnapore.	By sloop by the sea.	By steamer and by boat from Chandbali.	By steamer to False Point and thence by boat.		
	Per Ton. R a. p.	Per Ton. R a. p.	Per Ton. R a. p.	Per Ton. R a. p.	Per Ton. R.	
Jellasore	13 8 0	...	...	...	3·50	There is no steamer running to Balasore. When there was a steamer, the rate was Rs. 15 per ton. The rate of carriage from Jellasore will be less than that from Balasore, as it is nearer to Midnapore.
Balasore	17 8 0	11 0 0	...	...	4·09	
Chandbali	...	...	11 8 0	...	5·51	
Cuttack	...	...	19 8 0	23 0 0	7·81	

"From the above table it will be seen that the traffic is paying at present for all stations, except for Chandbali, *three times* as much as it will pay when the proposed canals are made. For Chandbali the rate is double only, but this is simply owing to the competition between the two rival Steamer Companies in reducing the rates of freight, which are liable to go up again any day either of the Companies withdraw their steamer."

34. A careful scrutiny of Mr. Vertannes's report is needed to appreciate the care and pains with which these results have been deduced.

I extract the following particulars of the present charges :—

	Per ton. R a. p.
1. Calcutta to Cuttack *viâ* False Point—	
Shipping charges in Calcutta	2 8 0
Freight to False Point	15 0 0
Conveyance by boat to Cuttack	5 8 0
Total	23 0 0

This is about the same as from Calcutta to London.

	Per ton. R a. p.
Calcutta to Cuttack *viâ* Chandbali—	
Shipping charges in Calcutta	2 8 0
Freight, average	9 0 0
Conveyance by boat to Cuttack	8 0 0
Total	19 8 0

35. From Cuttack to Calcutta the prices are—

	Per ton. R a. p.
Viâ False Point—	
Boating from Cuttack to False Point	5 8 0
Steamer freight	9 0 0
Landing charges	2 8 0
Total	17 0 0

36. From Chandbali to Calcutta the charges are—

	Per ton. R a p.
Shipping charges	1 5 0
Freight (4 annas 9 pie per bag)	4 0 0
Landing charges	2 8 0
Total	7 13 0

Upon this Mr. Vertannes remarks—"The rate of 4 annas 9 pie per bag is what at present the actual charge is, owing to the competition between the two rival steamers. Mr. Clarke, who has been at Chandbali for the last eight years, informs me that 8 annas a bag would be an ordinary charge, as any tug steamer employed on the Hooghly would gladly at this rate come to Chandbali for cargo after dropping the vessel she was towing at sea. Taking 8 annas per bag as the usual freight, the freight for rice from Chandbali to Calcutta would be Rs. 10-5 per ton, instead of Rs. 7-13."

37. The freight per bag from False Point to Calcutta varies from 8 annas to 1 rupee.

38. In calculating the cost of carriage, Mr. Vertannes has been at great pains to analyse the existing charges on other lines, and has deduced the charges proper for the proposed canal. The most satisfactory test, however, of his rates is a comparison of them with those on other canals and rivers in Bengal. This Mr. Vertannes has given in a subsequent note in reply to some doubts expressed by the Collector of Midnapore upon this point. From this it appears—

(1) That the estimated cost of carriage of goods, exclusive of tolls, on the proposed canal, is 2·55 pies per ton per mile; the actual charge in Eastern Bengal is 2·27 pies, and for boats going from Calcutta to Baliaghye in Hidgellee *viâ* the Hooghly instead of canal 2·70 pies, with all the special risks of that route.

(2) That the estimated cost of carriage by canal, inclusive of tolls, is 5·52 pies per ton per mile, against 5·32 pies on the Midnapore Canal, the rate of toll being taken as the same in both cases.

(3) That for passengers the estimated cost, inclusive of all charges, is 1·64 pie per head on the proposed canal, against an actual charge of 1·28 pie on the Midnapore Canal.

39. Thus the rates assumed by Mr. Vertannes in his calculations are fully borne out by those on existing lines.

40. As, however, the objection raised by the Collector of Midnapore is one of great importance, it may be well to state it more fully, and to give the substance of Mr. Vertannes's reply.

41. Mr. Harrison in his report has expressed doubts as to the ability of the canal to compete with the sea-route from Chandbali, and has supported his views by a reference to the actual cost of carriage on the Midnapore line as compared with that assumed by Mr. Vertannes for the Coast Canal. He has, however, been misled by assuming that the actual charge for tolls would be the same on both lines. The rate of toll proposed by Mr. Vertannes is the same as that charged on the Midnapore Canal, *viz.*, 1 anna per 100 maunds per mile, or 3·24 pies per ton per mile; but the actual charge upon the latter is very much heavier than this in consequence of the system of measurement in force which greatly exaggerates the tonnage upon which tollage is charged. The measurement tonnage upon which tolls are levied is 2·16 times the actual, and as a large proportion of the boats return empty and also pay tolls, the additional charge on this account increases the total to 2·56 times the nominal. The actual charge for tolls on the Midnapore Canal, when boats carry a load only one way, is thus 2·56 × 3·24 pies, or no less than 8·29 pies per ton per mile. The boatmen's charge is an anna per ton per mile, inclusive of the toll. Mr. Vertannes's proposed rate is 3·24 pies × 1·39 = 4·5 pies, including the empty boat. Applying this correction to Mr. Harrison's figures, Mr. Vertannes has shewn that his calculations of cost are correct. In the case of passengers, in which the toll levied is per head, and in which there is, therefore, no difference between the actual and the nominal charge, Mr. Harrison would have found that Mr. Vertannes's estimate of the total cost per head to Chandbali by canal is the same as the actual to Midnapore multiplied by the ratio of increase of distance. I may add that if the mileage rate of tolls on the Midnapore Canal seem excessive, on the other hand, the distance being short, the actual cost of export and import is small, and we have ample evidence of the benefits which this navigation has conferred upon the districts supplied by it.

42. Mr. Harrison has also pointed out that Mr. Vertannes has made no allowance for shipping and landing charges in the case of canal, though he has included both in the case of the steamers. Mr. Vertannes, however, in reply explains that these charges in the former case are always very small, and, moreover, that their omission is balanced by that of the cost of

carriage of all goods shipped from Chandbali to that place, and storage there, pending the departure of the steamers.

43. With regard to the passenger traffic, Mr. Norman, the Collector of Balasore, thinks Mr. Vertannes's estimate of 100,000 per annum by the proposed canal far too low, and would double it. Mr. Norman remarks—

" The following table shows the cost, in decimals of a rupee, of conveying each passenger from Calcutta to the principal stations along the line, according to the rates of toll proposed and the average cost of boats and crews, as arrived at by calculation :—

	Suburnrekha River.	Balasore.	Metai River.	Chandbali.	Pattamundi.	Cuttack.
Tollage	·275	·395	·582	·582	·582	·934
Cost of boat and crew . . .	·398	·521	·703	·868	·959	1·19
Total cost of conveyance . . .	·673	·916	1·285	1·450	1·541	2·124

"The assumed rates of toll, therefore, when added to the cost of boats and crews do not appear to be excessive or likely to kill the traffic, if compared with the rates of passage-money charged by the different Orissa steamers. A steamer running between Calcutta and Balasore used to charge from R2 to R3, and considerably more at times of pressure. The Chandbali steamers now charge from R2-8 to R3-8, and their tickets sometimes, on occasions of great demand, fetch as much as R15. I therefore consider that the above rates of tollage when added to other conveyance charges would not be unduly high.

" The total number of passengers both ways, on account of whom tolls levied at the above rates would amount to R81,400, as mentioned above, is estimated at 100,000, who have been roughly distributed thus—

Between the	Suburnrekha	and Calcutta	5,000
Ditto	Balasore	ditto	10,000
Ditto	Chandbali	ditto	40,000
Ditto	Cuttack	ditto	45,000

" Uriyas are much employed in and about Calcutta as domestic servants, as palanquin bearers, and in work connected with the shipping, &c. The number of Uriyas who travel between their homes and Calcutta is notoriously very large Again, immense numbers of pilgrims are attracted into Orissa by its celebrated shrines, among which those of Jagannath, Bhubaneshwar and Jajpur are the principal. In February last, the number of pilgrims assembled at Pooree alone amounted to the large number of 340,000. In spite of the fact that a certain number are drawn off by the steamers, the Orissa Trunk Road may be said never to be without pilgrim traffic; and at the principal festivals it is absolutely crowded with continuous streams of travellers in vehicles of all descriptions and on foot. The steamers are exceedingly inconvenient and distasteful to natives. Both the Chandbali steamers arrive and depart on .the same days, and passengers arriving at Chandbali from the interior have sometimes to wait almost a week for their steamer. Chandbali is, during the rainy season, a place exceedingly difficult of access by land, as the routes leading to it consist of tracks which become entirely submerged for long distances together, and to considerable depths. In the steamers the passengers are packed together very much like sheep; the females, except first class passengers, have no secluded accommodation; and males and females alike are half starved during the voyage, as caste prejudices forbid their eating cooked food on board. In spite of all these drawbacks, the Chandbali steamers during 1876-77 carried 66,880 passengers, and would have carried more had their carrying capacity at times of religious festivals been greater. On such occasions, indeed, the temptations to overcrowding are very great, and overcrowding sometimes occurs. Masters have three times been convicted of it and punished very heavily during the past three years. Under these circumstances, there can, I think, be no reason to doubt that were a canal made, the whole of the passenger, traffic now carried by steamers would be transferred to it. I feel convinced that the prospects of a good passenger traffic are highly promising; and I think that there is every reason to consider that the estimate of 100,000 passengers is much too low. It only exceeds by one-third the number at present carried by the steamers to one point, Chandbali. It makes no allowance for intermediate traffic, of which the quantity would be not inconsiderable, as, for instance, between Balasore and Cuttack. The population of Orissa with the Tributary Mehals is 4,317,999. The number of pilgrims to Pooree alone is estimated by Hunter at 300,000 per annum. (Orissa, Volume I, page 150.) Looking to all the facts, I have no hesitation in stating my opinion that the estimate should be doubled. I think the canal might fairly be expected, even at the first, to carry 200,000 passengers per annum."

44. The number of passengers carried on the Midnapore Canal, only 48 miles in length, last year was 137,000. There can be no question that the number would be very much greater on a line of such immense intercourse as that between the Hooghly and Orissa.

45. The following statements show in more detail the estimated cost of transport to different points along the coast and to Cuttack :—

Goods.

	DISTANCES FROM CALCUTTA.			COST PER TON.			Cost per ton per mile.
	River.	Canal.	Total.	Boat charge.	Tolls.	Boat charge and tolls.	
	Miles.	Miles.	Miles.	R	R	R	Pies.
Balasore	52½	81½	134	2·18	1·91	4·09	5·86
Chandbali	86	119	205	2·72	2·79	5·51	5·16
Cuttack	91	179	270	3·64	4·21	7·85	5·58

Passengers.

	DISTANCES FROM CALCUTTA.			Boat charge per head.	Tolls per head.	Total per head.	Total per head per mile.
	River.	Canal.	Total.				
	Miles.	Miles.	Miles.	R	R	R	Pies.
Balasore	52½	81½	134	·765	·395	1·16	1·66
Chandbali	86	119	205	1·12	·582	1·70	1·59
Cuttack	91	179	270	1·44	·934	2·37	1·68

46. And now as to returns. In calculating these, Mr. Vertannes has assumed that the canal would take all the traffic that now goes by sea and land from Balasore to Calcutta, and all that by sea between Calcutta and Chandbali and False Point; and he has calculated the amount of this traffic for the most part only at what it now is, in a few cases only allowing for a small increase. Thus, in statement Z, he shows that the actual exports of rice to Calcutta from the Suburnrekha, Balasore, and Chandbali for the past four years have been 509,323, 697,450, 342,103 and 283,032 cwt., the average being 457,977 cwt. He assumes a traffic of 500,000 cwt. only on the canal. His quantities are mostly taken from the Custom's returns, and Mr. Norman remarks:—"I have satisfied myself, so far as my very limited time will permit, of the care, diligence and fidelity which have been bestowed upon the compilation of his statements." In one important item only, that of the present export of paddy *viâ* Baliaghye, his estimate is conjectural, but it is more than confirmed by independent calculations of the Collector of Midnapore. Mr. Vertannes's estimate of the exports from Cuttack has been attacked by Mr. Beames, but has been fully vindicated by Mr. Vertannes, who has shewn that Mr. Beames was betrayed into error by not (apparently) reading the heading of the statement, the accuracy of which he impugned, and which he understood to represent the total exports from False Point (which Mr. Vertannes had assumed would go by canal), whereas the statement merely contains the exports to Calcutta. As to the question whether the canal would or would not carry off all the present sea traffic with Calcutta, the point is really not worth discussion, for a line of communication which would reduce the cost of transport one-half, without at least doubling the previous traffic, would be a thing unheard of, so that, if the whole of the existing traffic continued to follow the present routes, Mr. Vertannes's calculations of returns would remain unaltered. But in truth his estimates of traffic trom the Mahanuddy Delta and Cuttack are far below the mark. He reckons, for instance, on only 5,500 tons of rice from False Point, leaving out of sight the immense area of country the produce of which would be brought to that point from Pooree on the south, and from Cuttack and the Brahminee on the west. He in fact has calculated on no larger export of rice by canal than now goes by sea, whereas I have shewn that, taking the present grain traffic of Hidgellee as a guide, the quantity might, with cheap canal carriage, be double or treble that amount.

47. Mr. Vertannes' estimate of returns is given in statement Z, and may be summarized as follows:—

	Goods Traffic.	Proposed tolls per 100 maunds.	Revenue.
Revenue from Goods Traffic.	Mds.	R	R
1.—*Direct.*			
Section I—of proposed Canal, Russulpore River to Suburnrekha .	25,24,000	2·61	65,876
Ditto II—of ditto, Suburnrekha to Balasore	15,41,600	2·05	31,603
Ditto III—of ditto, Balasore to the Metai	8,60,600	3·26	28,056
Total Direct Revenue . .	......	......	1,25,535
2.—*Indirect.*			
Range I—of present Tidal Canal	11,53,000	0·96	11,068
Ditto II—of ditto ditto	11,53,000	1·48	17,064
Kendrapara and Gobri Canals in Cuttack	2,15,600	3·67	7,912
Total Indirect Revenue . .	......	......	36,044
Total estimated Revenue from Goods .	......	......	1,61,579

	Number of Passengers.	Proposed tolls.	Revenue.
Revenue from Passengers.		R	R
Direct.			
Section I—of proposed Canal	100,000	·168	16,795
Ditto II—of ditto ditto	95,000	·133	12,635
Ditto III—of ditto ditto	85,000	·217	18,445
Total Direct .	......	......	47,875
Indirect.			
Range I—of Tidal Canal	100,000	.062	6,200
Ditto II—of ditto	100,000	·096	9,595
Kendrapara and Gobri Canal	45,000	·277	12,465
Total Indirect .	......	......	28,260
Total Passenger Revenue .	......	......	76,135

ABSTRACT.

	R
Goods Revenue	1,61,579
Passenger „	76,135
Total estimated Revenue .	2,37,714

48. This total differs by R8,650 from that given in Mr. Vertannes's statement, the difference being the estimated revenue from the Hunsooa and Gobri Branch Canal, which, it will be recollected, I have left out of the scheme.

49. There is an important error in the above calculation. Mr. Vertannes has omitted from the anticipated traffic on Ranges I and II of the exisiting Tidal Canal the 9,34,000 maunds which are sent by land from the direction of Balasore to Baliaghye, because, as he says, "this quantity already either passes through Ranges I and II or goes round by the Russulpore and Hooghly." But the traffic returns of the Tidal Canal show that it does not go that way, and no doubt it takes the cheaper river route on account of the heavy land carriage it has to bear before it reaches the water. But as the whole of this would certainly go by the proposed canal to the Russulpore, it would also go on thence by the present Tidal Canal, and therefore should be included in the returns. It would not go by the Hooghly, first, because the boats would not be adapted to that navigation, and second, because it is proposed to put tolls on

that line of carriage which will make it no cheaper than the canal. This will add R22,600 to the receipts, and so raise the total estimated revenue to R2,60,000.

50. This amount being in excess of what is required to cover intererst and working expenses, it is perhaps needless to note that, if Mr. Norman's estimate of the probable passenger traffic is to be taken, this would add another R70,000 to the receipts, and that Mr. Harrison points out that Mr. Vertannes has taken no credit for any miscellaneous receipts, always an item of revenue on other canals, and which he thinks might certainly be put down at R12,000. It is satisfactory that both the Collectors who have criticized Mr. Vertannes' estimates of revenue would increase rather than lower them.

51. Mr. Norman also remarks—

> "I observe that in the estimate no credit is taken for an increased trade in salt. The district at present manufactures its own salt to the extent of about, 1,50,000 maunds per annum. The proposed canal would run right through the saliferous lands; if, therefore, the salt manufacture were to continue, the canal would carry nearly all the manufactured salt to different parts of this district, and possibly also to the Cuttack District. Liverpool salt, however, maintains such a constant, and in most instances successful, struggle with the country-made article, that the slightest advantage gained by it may give it the victory, and there is reason to fear that the reduction of freights between Calcutta and this district might enable it to drive the home-manufactured article out of the market; in that case the canal would carry from Calcutta the salt required for the annual consumption of a considerable portion of Orissa."

52. Working expenses is an item which I find it impossible to estimate with anything like precision, the data being insufficient. The conditions in a salt-water Tidal Canal for navigation only are so different from those in a fresh-water irrigation and navigation canal, that the results obtained in the latter class of works would not be applicable even if they were sufficiently extensive, which in Bengal they are not, to afford a safe basis of induction. I give below the actual expenses of maintaining and working the Hidgellee Tidal Canal for five years. The figures for the current year are the amounts of sanctioned estimates only, but may be safely taken, as the year is so near its close:—

	1873-74.	1874-75.	1875-76.	1876-77.	1877-78.	Total.
	R	R	R	R	R	R
Navigation works	4,373	1,691	6,895	2,972	1,933	...
Buildings	813	1,669	539	1,355	2,025	...
Earthwork, ordinary maintenance .	1,374	12,575	5,176	3,310	3,665	...
Silt clearance	31,159	8,088	14,156	...	15,645	...
Total Works .	37,719	24,023	26,756	7,637	23,268	...
Establishments	3,148	9,212	10,640	4,364	5,000	...
Tools and plant	341	1,299	1,642	429	500	...
Total .	41,208	34,534	39,038	12,430	28,768	1,55,978

From these amounts the following deductions are to be made:—

R23,159 on account of silt clearance in 1873-74; this sum having been spent simply in removing the deposits which took place during the years previous to the completion of the locks when the canal remained open to the flow of the tides. The locks were only finished in 1873-74.

R7,645 on the same account in the current year, as the clearance will suffice for at least two years; the Executive Engineer reckons three.

R6,000 for special earthwork in 1874-75 not properly chargeable to current repairs and R4,319 on account of "porte valets" added to the Huldee locks in 1875-76, chargeable to capital. These four sums aggregate R41,123. The proportionate share of embankment and other charges is R11,000, and the total to be deducted R52,123. Taking this from the total of the five years, there remains a balance of R1,03,855 as the true cost of working the canal for this period. This includes establishments for working the locks, as well as toll collectors. The average per annum is R20.771, and the canal being 28 miles in length, the mileage cost is R742.

53. In considering how far this rate may be applicable to the proposed canal, we have to bear in mind—

(1) That the number of locks in the Hidgellee Canal is one in every 7 miles; in the proposed canal it will be one in 10 miles at most, or, if the short reach next Balasore be left open, 1 to every 14 miles.

(2) That the Hooghly and Huldee Rivers carry much larger quantities of silt than those from the south.

(3) That in the proposed canal the water will, as a rule, be below ground level, instead of, as in the Hidgellee Canal, some feet above it—a circumstance that tends to reduce the cost of maintenance.

(4) That during the rains the proposed canal will be fed to a great extent by the drainage water of the country which will bring scarcely any silt with it at all.

54. The conditions, then, of the proposed line are such as to justify the expectation strongly insisted upon by Mr. Vertannes, that the mileage cost of maintenance will be less than in the Hidgellee Canal. I think it may safely be assumed that it will not exceed R800, and may perhaps be kept down to R600.

55. Taking the higher figure, the cost for the whole 91 miles of canal will be R72,800.

56. The annual charge will thus be—

	R
Interest 4½ per cent. on 33 lakhs	1,48,500
Working expenses	72,800
Total .	2,21,300

57. The income from tolls may be taken at R2,60,000 to R3,30,000 according to the amount at which the passenger traffic may be estimated, exclusive of any receipts from miscellaneous sources or from such a traffic in salt as that referred to by Mr. Norman, or in timber, lime, wax, lac, &c., and other produce of the Gurjats of which Mr. Vertannes has taken no account.

58. Indirectly, of course, the profits from the canal arising from the increased value it would impart to the produce of Orissa would be very great. A reduction of even R4 per ton in the cost of export, which is less than what the above tables indicate as probable, would be at the rate of R3 per acre, taking the yield at 20 maunds, or double the present water-rate. Such a reduction might be facilitated by a better adjustment of the toll charges, adapting them to the distances goods are carried, and not levying one uniform rate all through, as assumed by Mr. Vertannes. It is probable, too, that the receipts may admit of a lower toll being charged for long distances without increasing the rate for shorter journeys. Even with rates of toll such as those proposed in the tables, the cost of export from Patamundi, which is near the centre of the Mahanuddy Delta, comes to only R4·73, or very little more than the present cost from Midnapore to Calcutta. The probable effects may be judged from the following extract from Mr. Harrison's report :—

> "The Midnapore Canal has permanently cheapened salt in the bazar by 15 per cent. It has undoubtedly added to the value of rice, though, owing to the fluctuations in this grain, it is difficult to give the precise amount. It has added greatly to the value of jungle produce and timber ; and, in short, I am collecting evidence which tends to show that it has raised the value of landed property within the area tapped by it to the extent of 25 to 200 per cent. It is certain that the land opened up by the canal is improving so rapidly in value that it sells at for 26 to 35 times the profits. Orissa is temporarily settled, and the facilities of trade which the canal must infallibly bring to at least some part of the country will tell upon the next assessment of land revenue."

59. Mr. Norman does not appear to overstate the case when he remarks—

> "In conclusion, it only remains for me to express my conviction that a navigation canal connecting Calcutta with the existing system of Orissa Canals would give, as it were, new life to the province, and would inaugurate an area of vastly increased commercial and agricultural prosperity. Increased facilities for export would re-act upon import traffic, for experience of the province shows that the demand for imported goods is in strict correlation with the purchasing power of the people ; and in a non-manufacturing country like this, the purchasing power of the people depends entirely upon the quantity of their produce which they are able to sell and upon the prices obtained for it."

60. Having thus stated the results of the investigation of this project, and shewn that they all tend to confirm the expectations of its promoters as to its importance and remunerative character, it is right that I should point out that the canal will not, and from the circumstances of the case cannot, except at a very much heavier outlay, be an absolutely perfect work of its kind. So far as we yet see, it may be necessary to close it for silt clearances for two months in every second or possibly every third year, unless this can be avoided by a very much more extensive and successful resort to dredging than has hitherto been attempted. I cannot but believe myself that this will be found perfectly practicable, and that when once the necessity of avoiding such closures is forced upon us by the very magnitude of the traffic, the necessary

ways and means will be found. That which has hitherto led to the employment of manual labour instead of machinery has been its superior cheapness, and as the Hooghly affords an alternative route while the Hidgellee Canal is closed, and the loss in tolls during closure has been only a matter of a few thousand rupees, it was better perhaps to adhere to this simple and primitive mode of clearance. But the case will be very different when the canal becomes the channel for the whole Orissa trade, and no doubt it will be found possible to substitute machine dredging for the methods hitherto employed.

61. It might also occasionally happen, though it could very seldom be the case, that a steamer arriving at a lock at low water spring tides might be detained for an hour for want of sufficient water over the lower sill, but this would be a matter of no consequence. In connection with the question of steam traffic, I may mention that the steamer now on the Arrah Canal does the journey up from Arrah to Dehree regularly in 10 hours, the distance being 58 miles, or at 6 miles per hour, lockages included. If we reckon on a similar speed on the proposed Coast Canal, in which the locks will not be half as numerous in the same distance as on the Arrah Canal, the trip from Calcutta to Chandbali would be made in 35 hours instead of 44* by sea, and to Cuttack in 45 hours instead of 90 *viâ* False Point.

* This is the time the passengers are actually kept on board.

F. T. HAIG, *Colonel, R. E.,*
Chief Engr., Bengal, Irrign. Branch.

The 15th February 1878.

From Colonel F. T. Haig, R. E., Joint Secretary to the Government of Bengal, in the Public Works Department, Irrigation Branch, to the Secretary to the Government of India, in the Public Works Department,—No. 1069-I., dated Fort William, the 22nd March 1878.

I am directed to submit a note* by the Chief Engineer on a project for a canal to connect the present Tidal Canal in Hidgellee with the estuarie of the Orissa rivers and Cuttack. The note is so full that it may be sufficient to refer you to it for details, but the general outline of the scheme is as follows.

* Dated 15th February 1878.

2. The Tidal Canal connects the Hooghly with the Russulpore River. The proposed canal is intended to continue the navigation southwards along the coast, past Balasore to the head of the Metai, a large creek, or rather tidal river, falling into the Brahminee near its mouth. From this point the connection with the Mahanuddy, False Point, Cuttack, and the backwaters and creeks in the Pooree District will be made by means of canals already constructed as part of the irrigation scheme, or by new works to be constructed from Local and Provincial Funds.

3. Some of the latter have already been ordered to be commenced. The Lieutenant-Governor during his recent tour discussed the whole question with the District Officers of Cuttack and Balasore; and a scheme was laid before him by the Superintending Engineer for certain cuts to connect the various estuaries and tidal creeks by which, at a cost of about 1½ lakhs of rupees, navigation may be extended from the Brahminee to within a few miles of Pooree. This scheme has been sanctioned; funds have been placed at the disposal of the Superintending Engineer for its prosecution; and it is hoped that within two years this coastal communication, nearly 100 miles in length, will be opened for traffic. South of Pooree the country is not quite so favourable, but it may probably be found that the canal may be carried on at a moderate expense to the Chilka Lake, which is already connected by canal with Ganjam. There will thus be complete inter-communication between the numerous tidal navigations of Orissa from the borders of Balasore on the Brahminee down to the Ganjam District. But still this great net work of waterways would remain, as now, isolated from the rest of Bengal were not some link provided to connect it with the Hooghly and Calcutta. This the proposed Coast Canal is intended to supply.

4. The total length of the canal will be 91 miles. It may be divided into three sections as follow:—

	Length. Miles.
Section I.—From Russulpore River to the Suburnrekha	30
„ II.—Suburnrekha to the Burrabullong and Balasore	23½
„ III.—Burrabullong to the Metai	37½
Total	91

5. The total estimated cost, inclusive of the usual book charges for interest and pensions, is 33 lakhs, or at the rate of ₹36,200 per mile.

6. The dimensions proposed both for canal and locks are such as will admit of steam navigation, and it is expected that when the communications are complete, the time of transit between Calcutta and Cuttack will be reduced to two days instead of five as at present.

7. The works proposed are of the simplest kind, and exactly similar to those already constructed in Hidgellee. They consist, in fact, simply of canals with a lock at the end of each section, and here and there a drainage escape. It was originally proposed to have a much larger and more expensive kind of canal on the same line, and the whole of the surveys and sections necessary for estimating had been carried out, and in fact detailed estimates for the canal were submitted; but as the cost was evidently beyond what would be remunerative, the Executive Engineer was ordered to prepare abstracts of fresh estimates for a canal and locks of smaller dimensions. This he has done, and it is from these that the general estimate has been prepared. Thus, although the estimate is approximate only, it has been drawn up from accurate data; considerable additions have been made by the Chief Engineer to the Executive Engineer's estimate, and the total probable cost is taken, as already said, at 33 lakhs.

8. The returns have been calculated, not from mere general assumptions as to the probable amount of traffic on such a line, nor even from data derived from other canals in Bengal, but after a most careful analysis of the actual existing traffic along the line of country which will be traversed by the canal. The Engineer's estimate of traffic has been scrutinized by the Collectors, who are all disposed to think it below rather than above the mark.

9. After deducting working expenses, it appears that the surplus reckoning on a traffic only a little larger than that now in existence, will be sufficient to meet the charge for interest and if, as there is every reason to expect, the canal not only attracts the present traffic, but developes it in anything like the degree that usually takes place where cheap communications are opened, there will be a direct, besides the very large indirect, profit from the outlay.

10. The Lieutenant-Governor strongly recommends the project for sanction. He looks upon this canal as a most necessary work, absolutely essential not only to give full effect to the large expenditure which has already been incurred on irrigation works and local communications in Orissa, but to the protection of the province from famine. Had this canal been in existence in 1866, there would, the Lieutenant-Governor believes, have been no famine at all. As to the remunerative character of the project, the Lieutenant-Governor is so thoroughly satisfied, that he is prepared to guarantee the interest upon the outlay.

11. With this assurance of the Lieutenant-Governor's approval of the scheme, and of the strong opinion he entertains of its value and importance, I am to solicit sanction to it at a total cost of ₹33 lakhs.

12. The detailed estimates will be put in hand immediately, and submitted as speedily as possible. The Lieutenant-Governor is very desirous that the works should be commenced not later than next November, and with that view will see that the preliminary operations required for taking up the land are carried out this season, so that no time may be lost in the actual acquisition of the land as soon as sanction to the scheme is received.

13. A list of enclosures is appended.

From COLONEL H. A. BROWNLOW, R. E., Officiating Deputy Secretary to the Government of India, in the Public Works Department, Irrigation Branch, to the Secretary to the Government of Bengal, Irrigation Branch, Public Works Department,—No. 182 I., dated Simla, the 3rd August 1878.

In reply to your letter No. 1069I., dated March 22nd, 1878, I am directed to state that, after very careful consideration of the documents forwarded with it, the Government of India regrets its inability to comply with the request of His Honor the Lieutenant-Governor of Bengal to sanction the project for a canal, to connect the Hidgellee Tidal Canal with the estuaries of Orissa, in anticipation of receipt of the detailed estimates.

2. There appear to the Government of India to be grave reasons for doubting the sufficiency of the present estimate of the cost of the work, stated at 33 lakhs of rupees in paragraph 5 of your letter under reply. This sum gives ₹36,200 as the rate of capital cost per mile of canal channel, and it is further stated in paragraph 7 of your letter that the proposed works are exactly similar to those already constructed on the Hidgellee Canal. Now, the capital cost of the Hidgellee Canal, including capitalization of abatement of land revenue and interest charges during construction, amounted to ₹23,09,629, or ₹82,500 per mile, the channel being 28 miles long. Making every allowance for the difference in the number of

the locks on the two canals, this sum is so largely in excess of the estimated cost per mile of the proposed new canal as to cause serious doubts of the accuracy of the latter.

3. These doubts are further confirmed by a perusal of the accompaniments of your letter The Officiating Commissioner of the Orissa Division describes the course of the proposed canal as "running across shifting sand, liquid mud, and bottomless morasses," and there are no plans, levels, charts, or sections showing spring level, either to disprove entirely the accuracy of the above-quoted description, or to show how far it is justly applicable. If any considerable portion of the canal is to run through ground of the treacherous nature described by Mr. Beames, it is extremely doubtful whether even the rates allowed by the Chief Engineer for earthwork will prove sufficient.

4. The question of sufficiency of rates is further complicated by the question of sufficiency of quantities. The remarks made by Mr. Walker, Superintending Engineer of the Orissa. Circle (in paragraph 4 of his No. 3118, dated December 8th, 1877) on the advisability of deepening the canal at least one-and-a-half feet, if the assumed minimum depth of six feet is to be maintained in the channel, commend themselves to the Government of India as sound and practical. The excavation of this lowest foot-and-a-half may, for any thing that is stated to the contrary in the papers forwarded by you, cost from R8 to 10 per 1,000 cubic feet. Again, a glance at the map shows that the canal, running right acrosst he drainage of the country, is liable to have much of the earth excavated from it washed back into the cutting, and to have these cuttings filled with water during each rainy season that may come upon it before the arrangements for passing drainage across it are complete. The bed of the canal being also well below the level of high tide, the excavation pits will run a constant risk of being flooded unless special precautions are taken to bank out the tidal water. These adverse conditions must necessarily increase the quantities of work to be done, and delay the completion of the canal. Due provision should also be made for unwatering flooded excavation pits, and this would apparently add considerably to the percentage allowed for contingencies.

5. Further, there is nothing to show the adequacy of arrangements proposed for carrying intercepted drainage across the canal. It is stated that the water level is to be kept generally below the surface of the ground, and the floods allowed to flow over the canal, special means of inlet and outlet being provided. But the effects of running a continuous line of bank across heavy surface drainage have been found, in so many cases, so injurious and productive of such heavy outlay on repairs, that the Government of India is compelled to ask for full information regarding the drainage areas, volumes, and conditions of discharge of all intercepted flood waters before it can express any opinion on the sufficiency of the arrangements proposed for disposing of them.

6. With reference to the remarks in paragraph 15 of the Chief Engineer's note on the proposed scheme, I am directed to observe that the establishment charges in the Irrigation Department of Bengal amounted in 1876-77 to 30½ per cent. on works and repairs, and to 31·46 per cent. on capital outlay in the South-West Circle, so that, if 20 per cent. only is charged for establishment on the proposed new canal, other works will have to bear an unduly high percentage under that heading. The proposal to transfer the plant required for the locks of the new canal from other divisions in which the works are completed would only be admissible, and in accordance with existing rules, on the understanding that a fair price should be allowed for all plant so taken, as a credit to the capital account of the works for which it was originally procured.

7. The charge for interest during construction has apparently been calculated at 4½ per cent. for 1½ years on the whole capital to be expended. But for the reasons given in paragraph 4 of this letter, it appears to the Government of India that it will take very much more than three years to complete the proposed canal, and the fact that it took ten years to complete the Hidgellee Tidal Canal seems to bear out this opinion. Should it take anything like ten years to complete the East Coast Canal, the charge for interest during construction will have to be largely increased.

8. Accepting as correct the most favourable estimate of returns upon outlay; there is a prospect of obtaining at some future time a direct return of about 6 per cent. on the established capital outlay of 33 lakhs. But the estimate of revenue seems to be considered very doubtful by some persons well acquainted with Orissa, and if, as appears to the Government of India most probable, the estimate of capital cost should be largely exceeded, the estimate of the ratio of returns upon outlay will have to be proportionately reduced. Further, there is nothing to show at what rate the revenue will grow, and any marked delay in reaching the full amount

required to give a net return of 4½ per cent. would materially affect the remunerative character of the scheme.

9. Under these circumstances, the Government of India is compelled to ask that it may be furnished with—

(I) An estimate showing, in full detail, the probable outlay under the various heads of works, establishment, tools and plant, leave and pension allowances, capitalization of abatement of land revenue, and interest during construction. This estimate should be accompanied, amongst other necessary plans, by a good chart showing the run of drainage and levels of ground in the neighbourhood of the line of proposed canal; by a longitudinal section showing surface of ground, bed of canal, spring levels, and levels of high and low tide along the various reaches of the canal; by sections showing spring and tide levels, and the nature of the various strata of soil, to a depth of at least 5 feet below sole of foundation pits, at sites of all masonry works, and by the information regarding cross drainage asked for in paragraph 5.

II. A statement showing approximately the amounts which it is proposed to expend year by year, while the canal is under construction.

III. The anticipated growth of revenue year by year, from the time the canal comes into operation until it attains its maximum.

Report by J. C. Vertannes, Esq., Executive Engineer, Balasore Survey Division.

The history and object of this scheme is fully described in Bengal Government Public Works Department Joint-Secretary's letter No. 1069 I. of the 22nd March 1878, and the papers accompanying it. It will therefore be necessary to treat of it in this report only in its engineering details.

2. The work proposed to be carried out now is the construction of four lines of navigable canals, required to connect Ranges Nos. I and II of the existing low level or tidal canals in Hidgellee, in the Midnapore District, with the Metai River, one of the tidal creeks branching off the Dhamra River in Orissa. The proposed four ranges of canals are as follow, *viz.*—

RANGE No. III.—Thirty-one and a quarter miles in length, and connecting the Bagda River, a branch of the Russulpore River, in Hidgellee with the Suburnrekha River in the Balasore District.

RANGE No. IVA.—Seventeen miles in length, and connecting the Suburnrekha River with the Panchpara River in the Balasore District.

RANGE No. IVB.—Six and a half miles in length, and connecting the Panchpara River with the Burrabullong River, a little below the station of Balasore.

RANGE No. V.—Thirty-eight miles in length, and connecting the Burrabullong River with the Metai River, also in the Balasore District. The total length of the proposed canals is therefore 92¾ miles, or say, in round numbers, 93 miles.

3. The proposed works are simply canals with level beds, connecting the different rivers intersected by them along the coast, and provided with terminal locks at each end to keep in the canal channel the requisite depth of water for navigation purposes. During the dry season, *i.e.*, from December to May, the canals will be fed by the tidal waters of the different rivers connected by them, and during the wet weather or "monsoons," *i.e.*, from June to November, the waters of the drainage intercepted by the canals will be utilized for their supply. The drainage intercepted by the canals will be provided for by means of "inlet and outlet sluices" in the canal side banks, and also by "flood escapes" wherever necessary.

4. I will now proceed to describe the proposed works in the following order, *viz.*—

I.—The termini of the canals on the different rivers to be connected by them.

II.—The lines of alignment of the proposed canals.

III.—The bed level, the bottom width, ratio of side slopes, tow-path, and side banks.

IV.—Supply of water for the canals and the minimum and maximum depths of water and widths of canals at water-surface.

V.—Disposal of the drainage intercepted by the canal.

VI.—Masonry works required for the canals.

VII.—Protective works required for the canals.

5. **Termini of the proposed canals, Range** No. III.—The northern terminus of this range has been placed on the south or right bank of the Bagda River, opposite to the village of Surpai, whence a tidal creek connects the Bagda River with Contai, the head-quarters of the Hidgellee Sub-division of the Midnapore District. The southern terminus of Range No. II, tidal canal, is at Kaleenuggur, about four miles below Surpai, at the bifurcation of the Russulpore River into the Bagda and the Mydakhallee rivers.

6. There is at present a proposal before the Revenue authorities of the Midnapore District to close the mouth of the tidal creek between Contai and Surpai, and to construct on either side of the dam protective embankments with the requisite sluices, both for the reclamation of the waste jungle lands on the two sides of the creek in question, as well as for the improvement of the drainage of low land near Contai, the drainage of which is now greatly obstructed owing to the silting up, and consequent deterioration for drainage purposes, of the bed of the creek mentioned above. It is further proposed to carry out this scheme for the dam, &c., across the creek near Surpai, in connection with the works of Range No. III of the proposed coast canals for Orissa, if sanctioned. If this be done, the northern terminus of Range No. III of the proposed canals can be removed to Baintghur, on the right bank of the Russulpore River, *just opposite* to Kaleenuggur. This will of course necessitate a change also in the alignment of the first 10 or 12 miles of the canal, as shown by the yellow dotted lines on the index map of this range,—*vide* sheet No. 3 of Book No. I. This change in the canal alignment, while increasing its total length by three miles, will, however, effect a saving of two miles of canal excavation, as it is proposed to canalize a portion of the tidal creek between Surpai and Contai. It is, however, not proposed to take credit for any saving at present due to this reduction in length of canal excavation, as it is not certain whether the proposed reclamation works will be ever carried out; and, even if sanctioned, it is a question whether, in consideration of the advantage of having the termini of Ranges Nos. II and III opposite to each other, and also of having the use of the channel of the tidal creek between Surpai and Contai for navigation purposes, it would not be just to appropriate towards the cost of the reclamation work any saving which may be effected in the estimate of Range No. III, from the fact of the two works in question being executed at the same time. I only mention here the circumstance of the case in order to avoid any further reference in case it be afterwards determined to combine the two works mentioned above, and carry them out at once and at the same time.

7. The southern terminus of Range No. III should properly have been on the left bank of the Suburnrekha River, which this range is to connect with the Bagda River. But owing to the excessive floods of the Suburnrekha River, and the incapacity of its channel to carry off its maximum discharge, the southern terminus of Range No. III has been placed on the Goocheeda River, about one mile from its junction with the Suburnrekha river near the village of Kalaburia,—*vide* sheet No. 9 of Book No. 1 of the accompanying plans. Before 1868 the embankment in the Bhograi pergunnah extended right close to the left bank of the Suburnrekha River to the west of the Kalaburia village, but during the extraordinary inundation of that year it was found that these protective works contracted the flood section of the river so much as to raise the flood level of the river to an unusual extent and to cause the destruction of the greater part of the embankments between the Bhograi village and the Suburnrekha River. It was therefore decided to retire the embankment in question to its present position to the east of the Kalaburia village, and since then there has been no breach in these embankments.

8. The Goocheeda River is a large tidal stream through which the drainage of a large area is discharged into the Suburnrekha River, and, as far as I have known it for the last 13 years, it has not deteriorated to any appreciable extent. Between its junction with the Suburnrekha River and the proposed site of the terminus of Range No. III canal, the width of the stream at surface of low water level is about 180 feet, and its depth from 12 to 15 feet, which will be more than ample for the class of boats likely to use the proposed canals. Considering the sandy nature of the bed of the Suburnrekha River, I think it is rather an advantage to have the terminus on a small, deep, and well-defined stream, like the Goocheeda, which is also remarkably free froms hoals. It is true that the terminus of Range No. III will not be exactly opposite to that of Range No. IVA, but this is a difficulty which cannot be avoided under the circumstances, as it is not advisable to impede in any way the present flood section of the river. After all, the two termini will not be very far apart, and even in floods, it will be a far easier and safer crossing down in the tidal portion of the river than in the upper reaches, suppose the high level were to be made and an anicut constructed across the river. It is to be remembered that in all these rivers in their tidal reaches, the floods, however violent, have always their velocities *decreased* during flood tides, whilst in the upper reaches of the river out-

side of the influence of the tides such is not the case, and the consequence is that during freshets all traffic except that of boats propelled by steam power is stopped.

9. The cross section of both the Bagda River as well as of the Goocheeda River are given in sheets Nos. 6 and 9 respectively of Book I of the accompanying drawings. It will be seen that the former river at surface of low water level has a width of over 300 feet and a depth of 20 feet, and that for the latter river the dimensions are 180 feet and 12 to 15 feet respectively, which will be quite ample for every description of boat likely to navigate the proposed canals.

10. The northern terminus of Range No. IVA has been placed near the Jamcoonda village,—*vide* index map given in sheet No. 4 of Book I of the accompanying plans. It may reasonably be asked why this terminus was not taken half a mile lower down the river, opposite to the village of Bascoona, on the left bank of the river. This would have saved only half a mile of river navigation, but increased the length of canal excavation by nearly a mile, besides placing the terminus in an *unhealthy marsh,* full of jungle and distant from all villages. Moreover, owing to the river channel near the Bascoona village bifurcating into two different channels, one leading to the Goocheeda River and the other towards Jamcoonda, there will always be a greater probability of shoals forming in front of the canal entrance if placed here in lieu of the proposed site.

11. The termini of Ranges Nos. IVA and IVB, and IVB and V, have been so placed as to interfere as little as possible with the flood sections of the rivers connected by them, *viz.*, the Burrabullong and the Panchpara rivers. There will be some inconvenience to the boat navigation owing to the termini not being exactly opposite to each other; but under the circumstances of the case, I do not see how we can avoid this difficulty, even if we were to embank the river. After all, the inconvenience will really be very little. As far as boats propelled by steam power are concerned, it is obvious that it will not affect much the length of their passage if they have to steam against the current for half a mile or so. The empty goods boats and the light passenger boats can be easily towed or poled against the currents, which, owing to the bar across the mouth of the river on the Orissa coast, are not so strong as in Bengal. As far as the heavy goods boats are concerned, from what I have seen of the native craft, I think the crew of such boats will not care to cross the rivers except at *high water or with the tide in their favour,* whether the terminal locks be made exactly opposite to each other or half a mile or so apart.

12. The southern terminus of Range No. V has been placed on the left or east bank of the Metai River, a little below the Charbatea village. The cross-sections of this river in the vicinity of the proposed terminus of the canal are given in sheet No. 17 of Book I of the accompanying plans; and on referring to these sections it will be seen that the average width of the river at surface of low water is over 130 feet, and its depth 12 to 15 feet, or about twice as much as that of the proposed canals. The Metai River is one of the finest natural tidal canals in Orissa, and, as far as I have been able to ascertain, has not deteriorated to any appreciable extent. The construction of Range No. V of the proposed canals will tend to throw into it a larger quantity of the flood waters, which will, I think, help to keep it in its present state, if not to increase its flood section somewhat.

13. Then, with reference to the general alignment of the proposed canals. The country through which the canals in question will pass is, with the exception of the ridge near the Jookee cross-embankment in Range No. III, and the ridge between the Kansbans and Talpudda rivers in Range No. V so *flat and open,* that there was not much difficulty in determining upon the proper alignment of the different lines.

Range No. III.—For the first seven miles the line is taken along the waste land on the left bank of the tidal creek between Contai and Surpai. At the 7th mile it crosses the Government protective embankment in the Paharpore pergunnah, and is then taken right across to the low tract of country known as the "Doobdah Jheel" at the 12th mile, whence it follows along the low land immediately to the north of the inner range of sand hills in Hidgellee up to Sarsuthpore at the 26th mile, where it again crosses the Government embankment into the Bhograi pergunnah, till it terminates on the Goocheeda River to the north-west of the Bhograi village. From its intersection by the Jookee cross-embankment at the 21st mile to its terminus on the Goocheeda River, this range is subject to the flood waters of the Suburnrekha River, and the necessary protection against the inundation waters has been provided for it, as will be explained when discussing further on the level of the crest of side banks of the canal.

14. Ranges Nos. IVA and IVB.—The greater part of the former range lies in the low tract of land known locally as the "Soolsa Pat," which is protected from the inundation waters by natural sand ridges to the east and west of it, and by artificial embankments to the

north and south. After leaving this Pat the line is taken through the low tract of land immediately to the west of the ridges on which the large and populous villages of Boolung and Sartha are situated. This portion of the line is of course subject to the inundation waters of the Panchpara River, also occasionally to those of the Suburnrekha River during extraordinary high floods.

15. The country through which Range No. IVB passes is also subject to be inundated by the flood waters of the rivers, and is perfectly flat for four to five miles on either side of it, and presents no difficulty to our taking the canal straight across, in almost one line, from the Panchpara to the Burrabullong River, at the Nolecoolee village, about four miles below the station of Balasore. Owing to the large quantity of drainage water which flows into the Burrabullong River above Nolecoolee, it was not considered advisable to take the canal further up. There was not, besides, much advantage in taking the canal a mile or two further up, as the high ground on the right bank of the river comes much lower, and the terminus of Range No. V could not have, except at great depth of cutting, been brought more than a mile or so further up. Moreover, taking the canal crossing further up, would have only taken us to a shallower part of the river, and where we could not have so conveniently allowed for the discharge of the spill waters of the river, between the termini of Ranges Nos. IVB and V. So long as the Burrabullong River itself is navigable up to the station of Balasore, it is not a matter of much importance whether the crossing of the proposed canal is a mile or two miles more or less distant from it. In fixing on the canal crossing we should give the preference to the convenience of the general traffic on the line, and not to that of any particular station on the line.

16. RANGE No. V.—The line of this canal, after leaving its terminus on the Burrabullong River, is taken right down to a little beyond the Gummai River, along the low tract of country between the sand ridges on the sea coast and the ridge which is the termination of the high lands to the west. The latter ridge, as will be seen from the detail surveys, is thickly studded with villages, and has only four gaps in it for the passage into the sea of the drainage of the lands to the west of it. The four gaps in this ridge are those through which the drainge waters of the Prag, of the Talpudda, and of the Kansbans nullahs, are discharged into the sea. A little beyond the Gummai nullah the inner ridge on which the villages are situated recedes from near the coast, but the line of the canal is taken in almost one straight line through a stretch of level country to the Metai River a little below the Charbatea village. The country through which this Range No. V is taken is generally flat, with the exception of the ridge between the Kansbans and Talpudda rivers. The canal in the portion between the above-mentioned two nullahs will be in rather deep cutting varying from 10 to 15 feet, but only for a short distance. This ridge cannot be avoided, and comes right down from the hills to the west of the Trunk Road. Portions of this range of canal will be liable to be inundated by the flood waters of the stream intersected by it. The disposal of this will be dealt with further on when the proposed drainage and protective works come under discussion.

17. The bed levels of the proposed canals have been determined with reference to the average spring tides of the cold season, when the rise of the tides is the *least*. The canals, as stated in paragraph 3 preceding, are to be supplied during the monsoons by the intercepted drainage waters, and during the dry season by the tidal waters of the rivers connected by them. The level of the drainage waters being always higher than that of the tidal waters, the canal bed levels have therefore been fixed with reference to the *latter* only, and which are at their minimum height during the cold season. Now, in calculating the requisite levels for the beds of the proposed canal, we have first to determine on the following points, *viz.*—

I.—Minimum depth of water to be allowed in the canals.

II.—The loss in depth of water in the canal, in the interval between two successive spring tides.

The minimum depth of water in canal has been fixed at 7 feet, which will still leave a margin of six inches to nine inches, as the draught of the *largest* boats navigating the canals will be about six feet three inches to six feet six inches. But then it is to be remembered that this minimum depth will only be for about eight or ten days at the outside in the 12 months, *i.e.*, during the spring tides of December, January and February. The interval between two successive spring tides is taken to be 10 days, *i.e.*, the period between the day that the tide rises to its maximum height to the day that its rise is the least, or from the first or 14th day of the moon to the 10th or 24th day, according as the spring tides are due to new moon or full moon.

18. The canals being provided with terminal locks, it is evident that once the level of water in the canals has been raised by a spring tide, it can only be reduced in level by loss due—*first* to evaporation off the surface of the water; *second*, leakage through lock and sluice

gates; and *third*, lockage of boats through the terminal locks. The loss by evaporation has been taken to be one-sixth of an inch in the 24 hours, as was found by actual observations during the *cold season* made in the Burdwan District in connection with the late Damoodah Canal Project. The evaporation on the coast will, if anything, be *less* than in the Burdwan District, as we have generally heavy dews in the nights during the cold season along the coast, and this will in some measure compensate for the evaporation of the day. At any rate in assuming the depth of one-sixth of an inch in the 24 hours in our calculations, we will be on the safe side, and, if anything, in excess of the actual quantity. The loss by leakage has been assumed to be at the rate of a continuous discharge of four cubic feet per second in the 24 hours. This will be more than sufficient, as the terminal locks are all to be fitted with wooden gates and sills, the leakage between which will be inconsiderable and small as compared with that through the iron gates and stone sills. During cold season the canal waters will always be under ground level, and there will therefore be no loss by leakage through the side banks of the canal. The loss by lockage will of course be that due to the number of times the terminal locks are to be worked in the 24 hours, for the passage of the boats using the canals.

19. In the accompanying statements marked A and A^1, I have shown in detail the daily loss of water in the 24 hours in each of the four different ranges of the proposed canals, both for a minimum bottom width of 40 feet and 50 feet, and for an average as well as the lowest spring tides of the cold season. It is evident that as each range is to be provided with a terminal lock at each end of it, the loss by leakage will be the same for all the ranges, irrespective of its length or bottom width. Taking a continuous discharge of four cubic feet per second, the loss in the 24 hours will be 4 + 60 + 60 + 24, or 345,600 cubic feet, as given in the statements A and A^1.

20. The loss by lockage will, as before stated, be simply that due to the number of times the locks are worked in the 24 hours. In the accompanying statement marked B, I have shown the proportion between the estimated traffic (*i.e.* the traffic required to render the scheme remunerative), and that what the proposed canals are capable of passing both during an *average* as well as the *lowest* spring tides of the cold season. It will be seen from this table that the proportion varies from about 10 to 1 for an average spring tide to 5 to 1 for the lowest spring tide of the cold season, and which only occurs once or twice during the 12 months, and that at a time when the traffic will be very *slack*, as the people will be busy everywhere in harvesting their crops of winter rice. In calculating the traffic in the statement B, I have assumed that each time a lock is worked, 80 tons of traffic will be passed in and out of the canal,—say 50 tons of exports and 30 tons of imports and empty boats. The locks being 150 feet in length from sill to sill, are capable of accommodating boats of an aggregate tonnage of 50 tons, as has been found to be the case from *actual observation* made in the Midnapore Canal, and from calculations made by me from the size of the boats in use in the Canals. In the statement B are shown the number of times that the terminal locks will probably be worked in the 24 hours during the cold season, and in calculating the loss by lockage as shown in statements A and A^1, these numbers will be used.

21. I will now proceed to explain how the quantities showing the daily loss of water by lockage have been calculated for statements A and A^1. Take the case of the Range No. III. Taking the level of the average spring tides to be 110·00 plus datum, and that the level of the water in the canal will in the interval between two spring tides be reduced by about 18 inches, or to 108·50 plus datum, the mean level of water in the canal will therefore in the above interval be $\frac{110{\cdot}00+108{\cdot}5}{2}$, or 109·25 plus datum. The mean level of the waters in the rivers connected by this canal is shown to be 103·50 during an average spring tide level of the cold season,—*vide* statement marked D. Therefore the mean difference of level for lockage will be 109·35—103·50, or 5·75 feet. Now, the length of the locks being 150 between sills, and width 20 feet, and after allowing for length of the upper sill and for batter of chamber walls, we have the mean contents of each lock full of water, *i.e.*, each time that the lock is worked, to be 155 feet × 21 feet × 5·75 feet, or 18,715 cubic feet. From this I deduct for displacement of 50 tons, at the rate 35·9 cubic feet per ton, or 1,795 cubic feet; this leaves the actual mean loss of water per each lock full for Range No. III at 16,920 cubic feet. Then as each terminal lock of this range is supposed to be worked 40 times in the 24 hours, the total loss of water by lockage in the range will be 80 + 16,920, or 1,353,600, cubic feet, as there will be a lock at each end of the range. The quantities for the other ranges of the proposed canals have been similarly calculated.

22. The loss due to evaporation, as shown in the statements A and A^1, have been obtained from the quantities given in statement D, where the loss due to evaporation for the

different canals at various levels of water are shown both for the whole length of each reach as well as for each mile separately. The loss of evaporation has been calculated simply by multiplying the mean width of the canal at surface of water by the length, and dividing the contents by 72, as the depth of evaporation in the 24 hours is taken to be one-sixth of an inch, or $\frac{1}{72}$ of a foot.

23. Having from statements A and A¹ the probable total daily loss of water in the different reaches of the proposed canals, and knowing the level of the average spring tides of the cold season, it was easy from this data to determine the requisite bed levels for the canals in question. In statements marked E and E¹, I have given the calculations required for this purpose, and I will here explain the details of the statement for one of the ranges, No. III. Taking statement marked E for a minimum bottom width of 40 feet, the average cold weather spring tide level is shown to be 110·00 plus datum, as this is the level to which the canal waters will be raised during the spring tides. Now, in statement marked A we have shown the daily total loss of water in this range will be 1,867,054 cubic feet, or 18,670,540 cubic feet for the interval of 10 days between two successive spring tides. Now, if we refer to statement marked C, we will see that for the canal with the minimum bottom width of 40 feet, the reduction of its water level from 110·00 to 108·50 plus datum represents a loss of 6,166,875 + 6,043,225 + 5,919,375, or 18,129,475 cubic feet. This leaves a balance of another five lakhs of cubic feet to make up for the total loss in the canal of 18,670,540 cubic feet in the interval between two spring tides, or (say) that the canal waters will be reduced by another ·05 feet, as from statement C. it will be seen that the reduction of another one inch in depth of the canal water at the level of 108·50 plus datum represents a loss of 967,604 cubic feet. The loss of 18,670,540 cubic feet in the interval between two successive spring tides will in Range No. III therefore reduce the level of its water by 1·55 feet, or from 110·00 to 110·00 — 1·55, or 108·45 plus datum. Then as the minimum depth of water to be allowed in the canal has been fixed at seven feet, the bed level of the canal must therefore be 108·45 — 7·00, or 101·45, or (say) at 101·50 plus datum in round numbers.

24. The bed levels of ranges Nos. IVA and V have been similarly determined. In Range No. IVB the bed level has been fixed with reference to the neaptide level, as the length of this range is *too short* to admit of its utilizing the supply it will receive in the spring tides for keeping up the requisite depth of water, and it is obvious that for such a short range it will be cheaper to lower its bed level than to give it the bottom width required to keep up the requisite supply of water between two successive spring tides. The bed levels of both Range No. IVA as well as No. IVB have been made one foot *lower* than necessary, in order to provide against any silt which may be brought into the canals when the inundation waters of the Suburnrekha or the Burrabullong River may cross it.

25. The bed levels of the different ranges of the proposed canals, as fixed by me in accordance with the calculations given in the accompanying statements, marked A, A¹, B, C, D, E, and E¹, are as follows, *viz.*—

Range No. III	101·50	plus datum.
„ No. IVA	99·00	
„ No. IVB	98·00	
„ No. V	101·00	

The datum line used in all the levels connected with these coast canals is the *mean sea level* at *Kurrachee*, as used almost all over Bengal and Upper India. This mean sea level has been taken by some to represent mean tidal level on the coast here, whereas it is actually *three* to *four* feet *below* it.

26. The canals were originally to have had a minimum bottom width of 40 feet, but owing to our having to raise the side banks in several places above flood level; and also to our increasing the width near the terminal locks, the mean bottom width of the several ranges is considerably *more*, as will be seen from the following table, *viz.*—

Name of Range.	Bottom width.	
	Minimum width.	Mean width.
Range No. III	40	50·00
„ No. IVA	46	56·08
„ No. IVB	36	40·00
„ No. V	40	43·30

In Range No. IVA the minimum bottom was raised to 46 feet, in order to provide for sufficient earth for the raising of the side banks above flood level. In Range No. IVB the minimum bottom width was reduced to 36·00, as the depth of excavation was rather heavy, and the reduction of bottom width is only nominal, as far as the wetted section of the canal is concerned, the minimum depth of water being *eight feet* instead of the standard *seven feet.* The length of this range is, moreover, so short that the reduction of a foot or so in the bottom width would not be much felt, even it did cause any inconvenience to the traffic.

27. Estimates have been also prepared for the canal excavation for a minimum bottom width of 50 feet, in accordance with the instructions of the Chief Engineer, as Government might, if it considered fit, sanction the canal of the greater bottom width. The mean width of the canal, with a minimum bottom of 50 feet, will be as given below :—

NAME OF RANGE.	BOTTOM WIDTH.	
	Minimum width.	Mean width.
Range No. III	50·00	56·00
„ No. IVA	46·00	56·08
„ No. IVB	46.00	50·00
„ No. V	50·00	51·25

The mean widths, for the same reason as that given in the preceding paragraph, are virtually more than the minimum of 50 feet. In Ranges Nos. IVA and IVB the bottom width has been made 16 feet, as the minimum depth of water in these two ranges will be one foot *more* than in the two others, and this will make the minimum width to be 49 feet, or *one foot* only *less* than the usual minimum width.

28. The ratio of side slopes in all cuttings in the proposed canal has been fixed at 1½ to 1. The soil is quite stiff enough to stand at this inclination, and I see no reason why we should increase the cost of the works by unnecessarily increasing the ratio of the side slopes. In Range No. I of the Hidgellee canals, where the soil is not at all so hard as in the proposed canal, the side slopes of the cuttings have a ratio of 1½ to 1, and have, moreover, to support as heavy a side bank as there will be anywhere in the proposed canals. In a navigable canal, in my opinion, the steeper the side slopes the better it is for navigation purposes, as the wash of the waves due to the passage of a steamer through the canals is *felt less,* and it is more convenient for boats of great draught to be alongside of the banks. The ratio of side slopes in all fillings, such as forming the tow-path and side banks of the canal, &c., to be generally 2 to 1, except in case where the side banks are to form protective embankments. The ratio of side slopes will in this case be 3 to 1 for the side facing the inundation waters.

29. The side banks of the proposed canals, wherever exposed to the inundation waters of the stream intersected by them, to be raised at least three feet *above* the level of the flood waters. The crest of the side banks in such places to be not less than eight feet, with side slopes of 2 and 3 to 1 on the canal and inundation sides respectively. In Range No. III it will be seen from the sections of the canal that the side banks for the first seven miles have been raised above the level of the cyclone-wave of 1874, which swept over a portion of Hidgellee, and was about the highest experienced in South Hidgellee. From the Jookee cross embankment to Sursuthipur, where the canal intersects the Government embankment of the Bhograi pergunnah, the north side embankment of the canal has been raised above the flood level of 1868. Between Sursuthipur and Bhograi this range will be protected by the Government embankments of Bhograi pergunnah against the Suburnrekha floods, which are also shut out from the rest of the range of canal by the cross embankment at Jookee. In Range No. IVA the portion of the canal between the terminal lock and the Soolsa Pat northern border embankment has its side banks on both sides of it raised above the flood level of the Suburnrekha River, which are kept out of the Soolsa Pat by the embankments on the north and south of it, and by the natural sand ridges to the east and west of it. The remaining portion of Range No. IVA as well as IVB has the side banks raised above the level of the inundation waters crossed by the canals. In Range No. V the side banks are everywere raised *three* feet above flood water level. The eastern side bank of the first three miles of this range has been raised sufficiently high to form a protective embankment against the Burrabullong River inundation waters.

30. The width of tow-path in all the four ranges of the proposed canals has been fixed at six feet, which is more than ample, as towing in India, at least in Bengal and Orissa, is always done by men ; cattle are never employed for this purpose, and I see no reason why the cost of the work should be unnecessarily increased. The width allowed, *viz.*, six feet, is quite wide enough either for the men employed for towing purposes or to serve as a bridle road for the use of the inspecting officers and subordinates. Making the tow-path wider not only increases

the original cost of the work, but also adds to its maintenance charges, as the surface of the roadway forming the tow-path ,from want of traffic, gets overgrown with grass and jungle, and makes it, besides, infested with all kinds of vermin. The level of the tow-path in Range No. III has been made 18 inches above the level of the highest water in the canal, and this highest water level may occur only for 10 or 15 days in the 12 months, whenever we have any extraordinary heavy fall of rain; ordinarily, the tow-path will be over *three feet* above the canal water level. In Ranges Nos. IVA and IVB, the tow-path has been made six inches above the highest local flood level, and this may be for about three or four days in every two years or so. Ordinarily, the tow-path in this range also will be about *three feet* above the highest water level of the canals in the rains. When the extraordinary floods come across these two ranges, the tow-paths will be about 18 inches below flood level, but this will only be the case for about *three* or *four* days in every *ten* or *twelve years.* I do not therefore see any necessity of raising the tow-path level merely because at their present level they are liable to be submerged for three or four days every 10 years or so, especially as all traffic along this range of canal will *then* have to be stopped. In Range No. V the level of the tow-path has been fixed at six inches above the highest flood level. This will be the case for only four or five days every two years or so. Ordinarily, the tow-path in this range will also be *three feet* above the highest canal water level during the monsoons.

31. I now come to the question of the supply of the proposed canals. As stated in paragraph 3 preceding, the proposed canals are to be fed during the greater part of the year by the intercepted drainage waters, and during the remainder of the year by the tidal waters of the rivers connected by the canals. The drainage waters are to be admitted into the canal through the various inlet sluices proposed to be constructed in the up-stream side bank of the canal. From the figures given in the statements A and A^1, it will be seen that the greatest daily loss of water, due to lockage, leakage, and evaporation in any reach of the proposed canal during the dry season is 1,880,762 cubic feet; during the monsoons the traffic might be larger, and (say) on this account and the greater amount of evaporation, &c., the daily loss of water in the canals is increased to 3,000,000 cubic feet. This represents a continuous discharge of 35 cubic feet per second in the 24 hours. Even if the inlet sluices discharged with a mean velocity of three feet per second, the discharge from the half waterway area of a single span will be sufficient to give the required supply, as the waterway area of each opening of the proposed inlet sluices is 24 square feet. There will therefore be no difficulty about the supply of the canals during the rains, as the number of the inlet sluices is not only large, but the sluices are so well distributed along the length of each range as to render it probable that there will always be drainage water flowing into the canal from one or other of the inlet sluices.

32. Then, as regards the supply of the proposed canals during the dry season. This is the chief difficulty we have to contend against in the maintenance of the low level canals along this coast, as the tidal waters during the spring tides usually carry large quantities of silt. It is against the entry into the canal of the silt, carried by the tidal water feeding the canal, that we have to provide. Hitherto in the reaches of the tidal canals in use in Bengal, both in the Midnapore District as well as in Hidgellee and in the Circular Canal in Calcutta, the tidal waters are allowed to enter the canal through the terminal lock. This usually leads to the deposit of silt in large quantities in the beds of the canals for a mile or so just next to the terminal lock. Considering that the tidal waters are allowed to enter the canals at a low level and with the full force of the tide, it is not surprising that, as soon as the force of the tidal waters entering the canal is checked after passing the terminal lock, the silt hitherto held in suspension by the waters should be deposited over the canal bed. The force of the tidal current is generally strongest at mid-tide level and between it and the full-tide level. It is unfortunately at this period that the tidal waters enter the canal through the lock, and in doing this pass over with considerable velocity the bed of the approach channel between the lock and river. There is generally a large quantity of *freshly deposited* silt over the bed of this approach channel, and this of course is stirred up and carried into the canal by the tidal waters which feed it, through the terminal lock. The silt thus deposited over the canal bed extends, however, only to about a mile or 1½ miles beyond the terminal lock. After that the deposit of silt is almost imperceptible, as the fresh tidal waters which enter the canal through the lock seems to push backwards to the centre of the canal, bodily as it were, the whole of the water in the first two miles of the canal, and which, of course, being free from silt, do not cause any deterioration of the bed level beyond. It is therefore obvious that if we can prevent the entry of the silt into the canal, we will not only reduce to the lowest possible extent the maintenance charges of the proposed canals, but also any inconvenience or interruption to the traffic due to the frequent clearance of silt from the canal bed.

33. In the proposed canals it has been decided not to allow the tidal waters required for the supply of the canals to flow in through the terminal locks, but through sluices specially designed for the purpose. The plan of the proposed sluices is given in sheets Nos. 1 and 2 of Book II of the accompanying drawings. The sluice shown on the above-mentioned sheets is for the Range No. III and partly for Range No. IV canal. In canal Range No. V, also partly in Range No. IV, the outlet sluices proposed for the discharge of the drainage waters in the monsoons will, during the dry season, be utilized for taking in the tidal waters required for the supply of the canals. From the plan of the proposed supply sluice it will be seen that the floor has been placed at a *high* level, only about *three* feet, below the level of the ordinary spring tides of the cold season, so that any silt which will enter the canal will be that contained in the upper three feet of the tidal waters at the outside, and this only on one day, *viz.*, that on which the tidal waters rise to the maximum level. On the other days that the tidal waters enter the canal only the upper foot or two of the waters will enter the canal. During the months of March, April and May, when the spring tides rise a couple of feet higher, the level at which the waters will be allowed to enter the canal will be raised by dropping in balk planks in the grooves of the sluice openings on the side on which the drop-gates are to be placed. As compared with supply of water through the locks, the tidal waters entering through the proposed supply sluices will carry little or no silt. The depth of water entering through the locks will vary from 16 to 20 feet over *freshly deposited silt* on the beds of the approaches between the rivers and the locks; whereas the tidal water entering the supply sluices will have a depth of one to three feet, and pass over channels at a high level and with beds containing little or no silt, for, if necessary, the beds of the channels between the sluices and the river can at a small cost be always kept *clear* of silt, specially as they will not be submerged by the neap tides. Moreover, it is to be remembered that it is only the top foot, or 18 inches of the tidal waters, which will enter through the sluices, and at a time when the tidal current will have lost much of its force; whereas the waters enter the locks just at the very time when the current is the *strongest*, and consequently the tidal water contains the largest quantity of silt, specially when it is considered that the level of the upper silts of the locks are from 10 to 12 feet below tidal water level. There is no doubt but that the proposed supply sluices will effect a *vast saving* in the maintenance charges of the proposed canals. What the precise effect will be it is at present impossible to state, as similar works have not been constructed elsewhere, and till the sluices are actually constructed and worked, we cannot exactly say to what extent the entry of silt with the tidal waters will be prevented. From the block plan of these sluices, as given in sheet No. 2 of Book II of the accompanying drawings, it will be seen that any silt brought in by the tidal waters will be probably deposited in the channel between the canal and the sluices, and this can be easily removed by small dredgers without interfering with, or causing any inconvenience to, the boat traffic through the canals. Perhaps it may be found necessary to make the channel between the sluices and the canals a little longer than as now designed. This is a matter of detail which can be carried out at the time of execution of work without adding much to its cost.

34. In the accompanying statements maked F and H I have given the calculations in detail for finding the waterway required for the proposed supply sluices on the Bagda River for Range No. III of the proposed canals. As the rise and fall of the tide during the cold season in the Rassulpore River is about the same as in the Hooghly River at Diamond Harbour, the tidal diagrams of the self-acting gauge at the latter place have been used in the calculations mentioned above.

35. I will now explain how the figures given in statements F and H have been worked out. Taking the first tide worked, *viz.*, that of 19th January 1878, the waters in the canal are assumed to stand at the level of 108·40 plus datum on this day. The tide on this day rose to 109·20 plus datum; therefore the mean tide level, as regards the supply of the canal was concerned, was $\frac{108{\cdot}40+109{\cdot}20}{2}$, or 108·80 plus datum. The mean head of water entering the canal would be 108·80—108·40, or ·40 foot. The floor-level of the sluice being at 107·00, the mean feeding area of each span will be 108·80—107·00 × five feet, or nine square feet. The velocity is calculated from the formula $v = 5 \sqrt{h}$ & b in this case is shown to be ·40 of a foot. The duration of supply, or the time that the tide takes to rise from the level of 108·40 to that of 109·20 plus datum, is taken from the diagram of the rise and fall of the tide annexed to the statement. From the above data the supply through each span is easily calculated, and as there are to be 20 spans, the total supply for the period for the rise of the tide from 108·40 to 109·20 plus datum is easily obtained, and is

shown to be 1,195,220 cubic feet. Now, in statement marked C is given the quantity required to raise by one inch the level of water in Range No. III canal, and this quantity is 986,562 cubic feet, when the level of water in the canal is between 108·50 and 109·00 plus datum. Having this information, it is easy to deduce from it the height to which the canal water will be increased by the entry of 1,195,220 cubic feet in the period of the rise of the tide from the level of 108·40 to 109·20 plus datum. The rise will be about ·10 of a foot, and the canal waters will therefore stand at the level of 108·50 plus datum. This level is used as the level of the canal water for calculating the supply taken into the canal during the next period of the tide, or when the tidal waters stand at the maximum height, or what is usually called the "slack water" period of the tide. The calculations for this period are the same as for the last, and it is found that the canal waters are now raised to 108·75 plus datum, which level is therefore carried forward to the period of the tide when its level falls from its maximum height, *viz.*, 109·20 to 108·75, the last level of the canal water. The entry of the tidal waters during this last period raise the canal waters to a level of 108·798 plus datum. But from this is to be deducted the reduction in depth owing to loss of water in the canal in the 24 hours, due to lockage, leakage, and evaporation, as given in statements A and A^1, and is shown to be 1,896,312 cubic feet, and this, from the figures given in statement C, is equivalent to the reduction of ·16 of a foot in the level of the canal water, which would therefore have, after being fed by a tide similar to that of 19th January last, stood at a level of 108·798 — 0·16, or 108·638 plus datum.

36. The calculation for the other days have been similarly made. In the calculation given in statement H for the high tides of March, April, and May, it will be seen that I have assumed the level of the sluice floor to be raised from one to two feet, so as to allow of only the first three feet at the outside of the top waters of the tide to get in. This can be easily done by dropping in balk planks in the grooves of the sluice openings, on the drop gate side of the sluice. There are no self-acting gauges on the other rivers crossed by the proposed canals, but the rise and fall of the tide is very nearly the same on the coast all through, as the Panchpara River has almost the same difference in the high and low water levels as the Russulpore River. The low water level in the two rivers is the same, and only the high water in the latter river rises a foot more in height. The calculations made for the former river will therefore stand good for the others also, specially as the self-acting gauge diagrams would only give us the duration of the particular periods of the tides, and we have the actual rise of the tides in the different rivers from observations taken by us, and it is not likely that the duration of the tides will be less when its rise and fall is about the same.

37. The supply of tidal waters for Range No. III it is proposed to obtain from the Bagda River for two reasons—*firstly*, as the tide during the cold season in this river rises a foot higher than the Suburnrekha River; *secondly*, owing to the high inundations which come down the Suburnrekha River. It will be expensive to construct the requisite supply sluices. Provision has, however, been made in the estimates for this range for remodelling the existing sluice in the Government embankment at Burtona in Bhograi, so as to convert it into a supply sluice which will help to raise the canal waters up to a level of 109·00 plus datum, as the cold season tides in the Suburnrekha do not rise higher. For the supply of Range No. IVA, owing to the height of floods in the Suburnrekha River, the supply sluice required for this range has been placed on the Panchpara River. There is only one supply sluice provided for this range as well as for Range No. IVB, as the proposed outlet sluices as well as some of the inlet sluices in the former range, can be utilized for the supply of the canal with tidal waters during the dry season. The supply sluice for the latter Range, No. IVB, has been also placed on the Panchpara River, which contains less silt than the Burrabullong River. For Range No. V no special supply sluices have been provided, as the number of vents of the proposed outlet sluices will be more than ample for the purpose of supplying the canal with tidal waters, which in this case is to be obtained directly from the sea by the different tidal creeks intersected by the canal. The number of vents allowed for feeding this range, No. V, as well as Ranges Nos. IVA and IVB, are a little in excess of that allowed Range No. III, but the cost of this excess waterway is not much, and as we have no regular diagram of the duration of tides in these ranges, and as the work has not been tested practically anywhere else, it is, I consider, *better* to provide a little in excess of the actual requirements, and thus be on the *safe* side.

38. Maximum and minimum depths of water, and widths of the proposed canal at water-surface. In the statements marked E and E^1 I have shown the depth of water in

the different ranges during the cold season. The average depth during the cold season may be taken to be eight feet, and the remainder of the year 10 feet. The average minimum mean width of the proposed canals at the water surface will during the cold season be 64 feet and 74 feet respectively, according as the minimum bottom width of the proposed canal is made 40 feet or 50 feet. The average minimum mean width during the rest of year will be 70 feet and 80 feet respectively, according as the minimum bottom width of the canal is 40 or 50 feet. In the statements marked E and E[1] I have shown also the average depths of water in the proposed canal during the lowest tides of the year, and which occur in December and January. The minimum depth of water in the canals, Ranges Nos. III and V, will on these occasions be reduced to 6·50 and 6·34 feet respectively. But these low tides only occur once or twice during the 12 months, and the minimum depth referred to above will only last for *a day* or two in each spring tide, or for *three* or *four* days at the outside in the 12 months, and cannot therefore cause much, if any, inconvenience to the boat traffic. The only boats the navigation of which will be impeded will be the heavy goods boats drawing over six feet of water. The possible detention of these boats for a day or two in the 12 months is not a matter of such consequence as to render necessary the further lowering of the beds of the proposed canals. Moreover, at the time that these low tides occur, the traffic will be very slack, as the people will be all engaged in harvesting their crops of winter rice.

39. DRAINAGE INTERCEPTED. RANGE No. III.—The principal drainage intercepted by this range is that which is at present discharged into the Peechabunee khall from the low tract of paddy-land known locally as the "Doobdah Jheel" or "Pat." The conditions under which the drainage waters from the up land to the north and west of this jheel are collected in it, and gradually discharged through the Peechabunee khall into the sea, were fully investigated and discussed in the scheme for the closing and sluicing of the Peechabunee khall, in lieu of the great sea dyke on the Hidgellee coast. The drainage waters of 114 square miles of country flows into, and is collected in, this low tract, and is then gradually discharged into the sea partly by the Baliaghye khall into the Bagda River, and partly by the Peechabunee khall directly into the sea. It is the latter portion of the drainage that the canal Range No. III intercepts. After a heavy fall of rain, the level of the accumulated drainage waters in the low tract is raised to 112·50 plus datum. The area of the low tract, the discharge of the accumulated drainage waters over which is intercepted by the canal, is 14 square miles,—*vide* sheet No. 3 of Book No. I of the accompanying drawing. For the safety of the crops growing in this low tract it is found that it will be necessary to provide waterway in the canal side banks for the discharge across it of a quantity of the accumulated drainage waters sufficient to reduce its level by four inches in depth in the 24 hours. This is equivalent to providing for a discharge of four inches of depth over the 14 square miles of the drainage water accumulated to the north of the canal, and intercepted by it. The reduction of four inches in depth over 14 square miles represents a discharge of 1,500 cubic feet per second. This it is proposed to provide for by an inlet sluice of 12 vents of five feet each on the north bank, and an outlet sluice of eight vents of five feet each in the south bank of the canal. The positions of the proposed sluices are given in sheet No. 4 of Book II of the accompanying drawings. The area of each opening of the proposed sluices is 24 square feet. The inlet sluice it is proposed to allow to discharge with a maximum head of one foot and with a mean velocity of 5 feet per second, and the outlet sluice with a head of two feet and a mean velocity of 7·5 feet per second. This will allow for a discharge of 1,450 cubic feet through each of the sluices, and is about what is required to reduce by four inches in the 24 hours the level of the accumulated drainage waters. This discharge, it is to be remembered, will only occur after an extraordinary rainfall, or once in five or six years at the outside. Ordinarily the discharge across the canal will be about one-fourth of that provided for in the proposed sluices, and the velocity of the waters entering the canal will then be scarcely felt. The level of water in the canal can always be regulated to the required level of 111·50 plus datum by means of the proposed outlet sluices, as also by the feeding sluices in the locks, and also, if necessary, by the supply sluice, so that there will not be any difficulty in reducing the canal water level, so as to permit, on occasions of extraordinary rainfall, of the requisite head of one foot being allowed to the drainage waters flowing into the canal through the inlet sluices.

40. In ordinary years no such regulation of the level of the canal waters will be required, as the drainage waters will not be accumulated to any great depth, and will, besides,

be permitted to flow into the canal, wherever it is found to be necessary, for the benefit of the crops on the low lands. In some years it will probably happen that the outlet sluices will not have to be worked more than once or twice during the monsoons. The level of the bed of the discharging channel of the proposed outlet sluice has been lowered to 104·5 plus datum, and as the depth of water of flowing over the floor of the sluice is 5 feet, the level of the water over the channel will also probably be 104·5 + 5·00, or 109·50, or 2 feet below the level of 111·50 plus datum, which will be the water in the canal. It is possible that this head might be increased if the level of waters in the Peechabunee khal below the proposed sluice happen to be very low, but the length of apron allowed to the proposed sluice will be sufficient for even a velocity of 10 to 12 feet per second. In my calculation, to be on the safe side, I have assumed the least possible head for the mean velocity through the proposed outlet sluices.

41. The remaining drainages intercepted by the Range No. III are unimportant and are stated below, *viz.*,—

1st.—Drainage discharged by the Bamoonea and Iktearpore khals intersected by the canals in the first seven miles of its length.

2nd.—Drainage intercepted by the canal in the protected area between the Government embankment intersected by the canal in the 7th and 12th miles.

3rd.—Drainage of portion of the lowlands in the Bhograi pergunnah, within the Government embankments, as intersected by the canal in the 26th mile and at its southern terminus.

The drainage hitherto discharged by the Bamoonea khal and the Iktearpore khal has been provided for by the excavation of a diversion channel to lead the drainage waters into the Bagda River about two miles above the northern terminus of the proposed canal Range No. III,—*vide* index map given in Sheet No. 3 of Book 1 of the accompanying drawings. The diversion cuts will be merely open cuts liable to the flow in and out of the tidal waters, as well as to the discharge of the drainage waters. The section given to this cut has been fixed from what has been practically found to be sufficient for the open cuts made for the drainage intercepted by Ranges Nos. I and II of the Hidgellee tidal canals. In open cuts liable to the flow in and out of the tidal waters, it is almost impossible to make any accurate calculations for the dimension of the channel.

42. The drainage intercepted between the 7th and 12th miles of the canal is about 6 square miles in area, and is that which at present is discharged chiefly by the existing sluice in the Government embankment, and known as the "Ankghurra" sluice. In former days the area of the sluice waterway in the Hidgellee used to be fixed haphazard, and it will be no advantage to us in making any use of the waterway of the existing sluice. In calculating the waterway required for the proposed inlet sluice for this drainage, I have allowed for a flow of two inches in depth in the 24 hours over the drainage area, or a discharge of about 55 cubic feet per second per square mile. For the 6 square miles the discharge required will be 6 × 55, or 330 cubic feet per second. The mean velocity through the proposed inlet sluice being at the rate of 5 feet per second, the waterway required will be 66 square feet or (say) an inlet sluice of three vents of 5 feet each of the same design as the proposed inlet sluice in the 13th mile. In the same manner, the drainage of the tracts intersected in the Bhograi pergunnah, and the area of which amounts to about 6 square miles, also have been fixed, and sluices provided for it in the 31st mile of the canal, both in the canal side banks, as also in the banks of the supply channel between the Burtona sluice and the canal.

43. RANGE No. IVA.—In dealing with the drainage intercepted by this range, I will divide it into two parts—*viz.*, *1st part*, the drainage intercepted in the Soolsa Pat; *2nd part*, the drainage intercepted between the Soolsa Pat and the Panchpara River. The drainage in the Soolsa Pat being that of land protected against inundations is easily provided for by means of inlet sluice, which will allow the drainage waters to flow into the canal. There are two inlet sluices required in this portion, and the waterway of the sluices have been fixed from that of the existing sluices in the protective Government embankments in the Pat. The canal between the Pat and Panchpara River intersects not only the ordinary drainage of the adjacent lands, but is also subject to be submerged by the inundation spill waters of the Panchpara River, and occasionally, during extraordinary floods, by those of the Suburnrekha River. The ordinary drainage is that at present discharged by the tidal creeks known as the Bullong khal and the Sartha khal, and is intersected by the canal in the 12th and 15th miles respectively. This drainage it is proposed to provide by means of catch drains excavated

nearly parallel to the line of the canal, as shown in Sheets Nos. 11 and 12 of Book No. 1 of the accompanying drawings. In addition to these new drains, provision has also been made for clearing out and deepening the existing drainage khals between the new cuts. The sections of these drainage cuts have been fixed in the same manner as those of the cuts for Range No. III. In excavating these drains it is proposed to leave gaps in the side banks corresponding to the proposed flood escapes in banks of the main canal. On this account the rates of earthwork for this work is a little higher than usually allowed for such works.

44. Then, with reference to the disposal of the inundation spill waters which cross the line of this canal as well as Range No. IVB. Before entering into this question, it is necessary, first, to describe the conditions under which the flood waters of the rivers inundate the low lands in question; and in order to fully understand this, reference is solicited to the detailed survey of the sea coast, showing the line of the sand ridges and the sections of the mouths of the different streams which intersect it,—*vide* Sheets Nos. 19 and 20 of Book No. 1 of the accompanying drawings.

From these surveys, &c., it will be seen that the line of the sand ridge along the coast forms, as it were, a regular dam which prevents the inundation waters flowing out into the sea, except through the channels of the Panchpara and Burrabullong rivers, and a couple of other small tidal creeks which intersect the ridge. In the index plan of Range No. IV, as shown in Sheet No. 4 of Book 1 of the accompanying drawings, I have given the levels of the country· both above and below line of canal, and from these levels it will be seen that there is a considerable extent of low and level lands on both sides of the proposed canal. In fact the low tract of land between the sand ridge on the sea coast and Cuttack Trunk Road form, as it were, an *immense reservoir* in which all the inundation water of the adjacent rivers and hill streams are collected, and gradually discharged into the sea by means of the rivers which intersect the sand ridge on the coast, as mentioned above. The extent of this inundated tract is shown as accurately as we can, from the levels in the index map of Range No. IV. From careful enquiries made by us, and which have been verified as far as we could by observations made by our subordinates during inundations, it appears after once the flood waters have inundated the low tract in question, it takes from two to eight days before the waters are all passed off the land. The duration of the floods depends of course on the height to which the rivers rise. Ordinary floods, which rise to 113·00 plus datum, do not remain for more than two or three days, whilst during extraordinary floods the waters remain over the ground for seven or eight days; but then this only occurs once in eight or ten years. If we look at the peculiar conformation of the country, with the limited area of waterways of the streams intersecting the sand ridge on the sea coast, and consider the large extent and depth of inundation water over the low country, I do not think there can be any doubt as to the duration of the floods as noted above.

45. In determining, however, the waterway to be allowed across the canal for the passage of flood waters, we have to consider not the duration of the floods over the ground level, but the period of the rise of the flood waters, from the time it begins to spill over the country till it rises to its maximum level. The waterway to be allowed in the canal ought to be sufficient to allow of the low tract between the canal and the sand ridge on the sea coast being inundated in the *same period* as it is now. As regards the actual discharge of the flood waters, after once it has reached its maximum height, the waterway already left in Panchpara and Burrabullong rivers between the terminal locks of Ranges No. IVA and IVB and V will be more than sufficient, as will be seen in comparing the sections of the mouths of these rivers at their intersection by the sand ridge on the sea coast with the flood sections between the terminal locks of the proposed canals. Looking at the extent of the inundated tract, it will be obvious that, if we do not provide for the discharge of the flood waters across the canal, when it is first rising over country level, the inundation of the low tract between the canal and the sand ridge on the coast will be considerably impeded. This will naturally cause a greater accumulation of the flood waters over the low country between the canal and the road, and of course raise the present flood level considerably, and thereby perhaps cause far greater damage to the country as well as to the canal than if we were to allow the flood waters to flow across the canal by means of the requisite flood escapes. The only damage which this may cause to the canal will be the deposit of a certain quantity of silt over its bed. The question of the probable deposit of silt, from the entry of the inundation waters into the canal, will be discussed further on; and I hope I shall succeed in proving that the fears of some on this head are *greatly exaggerated.* For the present it will be sufficient to assume that the occasional entry of the flood waters of the rivers will not cause the deposit of silt to any appreciable extent over the beds of the canals.

46. To determine the extent of waterway to be allowed across the canal, we have first to ascertain the following facts, *viz.*—

1st.—Area of low country subject to inundation between the sand ridge on the coast and the line of the proposed canals.

2nd.—The depth to which the low country in question is inundated.

3rd.—The period which the flood waters take to rise to their maximum height from the time they begin to spill over the country.

The area of the low country to be inundated is about 60 square miles. In calculating this area, I have not taken into account the portion lying between the sea coast and the Soolsa Pat, as this portion will be inundated more by the spill waters of the Suburnrekha River than of the Panchpara River. Taking the highest local flood, *i.e.*, the flood from the hill streams only, exclusive of the Suburnrekha spill, to be 116·00 plus datum, and the average level of the country to be 111·50 plus datum, the depth of the inundation waters over the country would be 4½ feet. The period of the rise of the flood from the time it begins to spill over the country till it reaches its maximum level has been ascertained from careful enquiries to vary from 36 to 24 hours; but, to be on the safe side, I will assume the latter, *viz.*, 24 hours, in my calculations. This period of 24 hours for a rise of 4·5 feet, or from 111·50 to 116·00 plus datum, allows for a rise 2¼ inches per hour, which is, if anything, rather excessive for the stream so low down near the sea coast. The rise of 4½ feet in depth over the area of 60 square miles is equivalent to a discharge of 60 × 1,452, or 87,120 cubic feet, or (say) in round numbers 90,000 cubic feet per second. To provide for this discharge we have flood escapes to the extent of 6,800, and 4,000 lineal feet in Ranges Nos. IVA and IVB respectively. In addition to this there are the spaces between the terminal locks on the Panchpara and Burrabullong rivers, and amounting to 2,300 and 4,700 lineal feet, respectively. The total lineal feet of waterway therefore allowed will be 10,800 + 7,000, or 17,800 feet. As the average level of the country and of the tops of the escapes is 111·50 plus datum, the mean depth of water flowing across the canal and over the open spaces, between the Panchpara and Burrabullong river terminal locks, will therefore be $\frac{116\cdot00 - 111\cdot50}{2}$, or $\frac{4\cdot5}{2}$, or 2·25. The superficial feet of waterway will therefore be 17,800 × 2·25, or 44,500 square feet. Allowing for a velocity of only 2½ feet per second across the canal, this will allow for a discharge of 44,500 × 2½, or 111,250 cubic feet per second, or about 21,250 cubic feet *more* than what is required. It will be observed that in the above calculations I have assumed that the velocity in the spaces on the river banks between the terminal locks will be the same as across the canal, whereas it is likely to be somewhat more, say, about 3 or 4 feet per second. To provide for the discharge through the channels of the Panchpara and Burrabullong rivers at their intersection by the sand ridges, I have not in the above calculations taken into account the discharge through the channels of the above two streams at their intersection by the canal, and have also on this account allowed for the additional discharge of 24,000 cubic feet. It is absolutely impossible, without actual observation of the flood level and velocities, to ascertain what will be the discharge of the two rivers at their mouths. But even if the discharge allowed for it be not sufficient, an increase of only six inches in the velocity of the flood waters across the canal will provide for a further discharge of 22,250 cubic feet per second, and a mean velocity of 3 feet per second is not considered *too much* to allow across a navigable canal.

47. Then, with reference to the provision for the discharge of the flood waters, during extraordinary inundations, when the flood waters are raised to the level of 118·00 plus datum. This only occurs once in every eight or ten years at the outside, and is due to the spilling of the Suburnrekha flood waters over its right banks from above Rajghat at its intersection by the Cuttack Trunk Road down to the Soolsa Pat northern border protective embankment. It is to be remembered, however, that this spill of the flood waters only occurs after the local flood waters from the Panchpara River and other adjacent hill streams have come down and inundated the low country, and already raised the flood level to 116·00 plus datum. In therefore providing for the discharge of the extraordinary flood waters across the canal, we have only to take into account the time that is occupied in raising the inundation waters from 116·00 plus datum to 118·00 plus datum. This, from careful local enquiries, has been found to be 12 hours, but, in order to be on the safe side, I have taken the time to be six hours only. To raise the flood level over 60 square miles by two feet within six hours will require a discharge of 2,581 × 60, or 154,860 cubic feet per second. Now, when the flood level is raised from 116·00 to 118·00 plus datum, the mean depth of the discharging area over the flood escapes and country will be $\frac{116\cdot00 + 118\cdot00}{2}$ — 111·50, or 117·00 — 111·50, or 5·5 feet. The length

of waterway, taking the aggregate length of the flood escapes in the canal banks and the spaces between the terminal locks on the Burrabullong and Panchpara rivers, is 17,800 lineal feet, as stated in the preceding paragraph. Therefore, the area of waterway allowed for the discharge of the extraordinary flood waters for raising the flood level to 118·00 plus datum will be 17,800 × 5·5, or 97·900 square feet. This, with a mean velocity of 2½ feet per second, will give a mean discharge of 244,750 cubic feet per second, irrespective of that passed off by the channels of the two rivers in question The actual discharge required to raise the flood-level by two feet in six hours will be 154,860 cubic feet per second. For the same reasons as that stated in the preceding paragraph, I have provided for a greater discharge than is actually required.

48. Now, with regard to the area of the waterway allowed across the proposed canals, Ranges Nos. IVA and IVB, as compared with the area of flood sections of the Burrabulong and of the Panchpara rivers, and of the other two tidal creeks which intersect the line of the sand ridge of the sea coast. The length of the waterway allowed in the canal banks and in the spaces left between the terminal locks is, as stated in the preceding paragraph, 17,800 lineal feet. Now, the depth of the inundation water over the country and the flood-escape beds will be 6·5 feet when the flood waters stand at 118·00 plus datum as the average level of the country, and the escape beds is 111·50 plus datum. The area of waterway will therefore be 17,800 × 6·5, or 115,700 square feet. Allowing for a velocity of only 2½ feet per second, the discharge across these will be 115,700 × 2½, or 288,750 cubic feet per second. To this is to be added the discharge through the channels of Panchpara and the Burrabullong rivers up to level of 111·50 at their intersection by the canal. The flood area of the channels of the above two ranges is 3,100 and 7,700 square feet respectively, or 10,800 square feet in all. Taking a mean velocity of 5 feet per second, the mean discharge through these river channels will be 54,000 cubic feet per second. So that the total discharge allowed to the inundation waters, during extraordinary floods, will be 288,750 plus 54,000 cubic feet per second, or 342,750 cubic feet per second. In the absence of any actual observation of the flood level and velocities at the mouth of rivers and creeks, intersecting the sand ridge on the sea coast during extraordinary inundations, it is of course impossible to ascertain with any degree of accuracy what is the true discharge through those streams into the sea. It is obvious that the level of the inundation waters, discharged through these creeks, will vary with the rise and fall of the tide, which varies from 96·00 to 112·00 plus datum on the coast. Making every allowance for this, I assume that the mean level of the inundation waters as discharged into the sea through the openings in the sand ridge to be 114·00 plus datum. This gives a sectional flood area of 44,762 square feet in the rivers and creeks noted below, *viz.*—

	Square feet.
Burrabullong River	17,417
Panchpara "	17,646
Bullong khal	5,766
Gobri khal, &c., and the small tidal creek to the north of it	3,933
Total	44,762

Taking a mean velocity of 5 feet per second through the rivers at their mouths, the actual total discharge will be 223,810 cubic feet per second, or 118,940 cubic feet *less* than that allowed across the canals and in the channels of the Burrabullong and Panchpara rivers at their intersection by the proposed canals.

The mean flood level of 114·00 plus datum, as assumed for the mean flood areas of the streams at their mouths, is rather high if we consider the rise and fall of the tides in the sea; but, to be on the safe side, and in the absence of actual observations, I have assumed a higher level in my calculations.

49. The mean velocity allowed is probably *much more* than what is actually the case, if we take into consideration the fact that during high-water in the sea the discharge through the rivers at their exits on the coast will be considerably retarded. In the absence of any actual observations, it is impossible to obtain any reliable information on this point; but I have, in determining on the flood waterway of the proposed canal, endeavoured to arrive at the truth with the best information I have been able to collect. Perhaps I may have allowed for a larger extent of waterway than what is actually required; but in such calculation, and in the absence of any reliable information as to the actual discharge of the rivers at their intersection by the sand ridges on the coast, I have thought it advisable to allow a little more and be on the safe side. It may possibly be asked why the necessary accurate information on this point was not procured. This, it is to be remembered, can only be obtained during

the occurrence of extraordinary inundations, which happen only once in eight or ten years; and as no such inundations have occurred during the period in which the information about this scheme was collected, the reason why we have not been able to furnish the required data is quite obvious. To actually obtain this information it will be necessary for Government to station for eight or ten years an officer of the rank at least of an Assistant Engineer to do nothing else save watch for the occurrence of extraordinary floods. This, for obvious reasons, is not done. In fact, if such were to done, it would be necessary to station Engineers for years in localities previous to the construction of any road or railway or canal. I do not see why an exception should be made in the case of the scheme.

50. For the discharge of the inundation waters across the canal, it is proposed to provide escapes or paved tow-paths at the level of the country. The plans of these escapes are given in Sheet No. 6 of Book No. II of the accompanying drawings. The level of the roadway of these escapes, it will be observed, is placed at 111·50 plus datum, or at the average level of the adjacent country. Now, it may happen that when the floods come down the rivers the level of the water in the canal will have fallen to below the level of 111·50 plus datum. To admit of the flood-escapes acting without doing any injury to the canal by flowing into it with excessive velocity, it is necessary that the canal waters should be as near as possible the level of 111·50 plus datum, or at the top level of the escape. To provide for this, inlet sluices are proposed to be constructed in the west side bank of the canal; this will allow of the local drainage water to flow into the canal and raise its waters to the requisite level. The waterway of the proposed inlet sluices have been determined as given below, *viz*.—

RANGE No. IV.—The mean bottom width of this range, as given in statement C, is 56·08 feet during the monsoons; the water level in this range of canal will probably be reduced by loss due to lockage, leakage, &c., to about 108·00 plus datum at the outside, or 3½ feet below the required level of 111·50 plus datum. The mean depth of water in the canal required for calculating the quantity of water necessary to raise it to the level of 111·50 will be $\frac{111·50 + 108·00}{2}$ — 99·00, the bed level of the canal, or 109·75 — 99·00, or 10·75. The mean surface width of the canal will therefore be 56·08 + 3 × 10·75, or 88·33 feet.

The quantity of water required to raise the canal water level to 111·50 will therefore be as follows, *viz.*—

Length of canal.		Mean width.		Depth required.		Cubic feet.
17 × 5,280	×	88·33	×	3½,	or	27,749,750.

The time required to raise the canal waters from 108·00 to 111·50 plus datum has been taken to be sixteen hours, as this is about the shortest period during which the drainage waters of the low land adjacent to and above the canal can enter the canal channel through the proposed inlet sluices. It is generally after a continuous heavy rainfall of 24 hours' duration that floods come down the river; but in my calculation I have, to be on the safe side, only allowed for sixteen hours. Then, with the above data, it will be easy to find what will be the discharge through the proposed sluices. I propose to allow a mean velocity of only 2½ feet per second, through the proposed sluices, so as not to have a greater head than three inches when the flood waters rise to over 111·50 plus datum and flow into the canals over the tops of the proposed escapes. The total quantity required to raise the canal water to 111·50 plus datum being 27,749,750 cubic feet, and the time allowed being 16 hours, the discharge per second will be $\frac{27,749,750}{16 \times 60 \times 60}$, or 480 per second. This, with a mean velocity of 2½ feet per second, will require a mean waterway of 192 square feet. Now, the level of the proposed sluices being at 107·00 plus datum, and the mean level of the waters in the canal being 109·75 plus datum, as stated above, therefore the mean feeding area of each vent of the sluices will be 109·75 — 107·00, multiplied by the width of the vent, or 2·75 × 5=13·75 square feet. The number of vents in the inlet sluices for this range being 14, the total waterway will therefore be 14 × 13·75, or 192·50 square feet, which is about the quantity required to raise the canal waters to the required level of 111·50. In the above calculations I have not taken into consideration the outlet and feeding sluices on the east side bank of the canal, as the shutters of these sluices will be naturally closed when the level of water in the canal falls to the level of 108·00 plus datum as assumed above.

51. Then, in the case of Range No. IVB. The surface of the water in this range I assume will fall to the level of 107·00 plus datum, at the outside, or the level of the high water of the neap tides of the monsoons. The mean level will therefore be $\frac{111·50 + 107·00}{2}$, or 109·25 plus datum.

The canal bed level being 98·00 plus datum, the mean depth here will be 109·25—9,800, or 11·25 feet, and mean surface width 50 + 3 × 11·25, or 83·75 feet. The length of this range being 6½ miles, the quantity of water required to raise its water-level from 107·00 to 111·50 plus datum will therefore be as follows :—

Length.		Mean width.		Depth.		Cubic feet.
6½ × 5,280	×	83·75	×	4½,	or	12,934,350

The time required to take in this quantity I have in the case of this range of canal allowed at 18 hours, as there is here no catch-drain above the canal as in Range No. IVA, and is not besides exposed so directly to the inundations as the latter range, or No. IVA. With the above data I find that the discharge per second required to be provided for in the proposed sluices will be $\frac{12,934,340}{78 \times 60 \times 60} = 200$ cubic feet nearly. This, with a mean velocity of 2½ feet per second, will require a mean waterway of 80 square feet. Now, the number of vents in the proposed inlet sluices is seven. The floors of the sluices being at 107·00 plus datum, and the canal water mean level being at 109·25 plus datum, the mean discharging area of the sluices will be 5 feet or the width of vent × 2·25, or the mean depth of water over floor level, or 11·25 square feet. The available discharging area of the sluices will therefore be 7 × 11·25, or 78·75 square feet. This is about what is required to raise, in the course of 18 hours, the canal water-level from 107·00 to 111·50 plus datum.

52. There remains now the disposal of the drainage, intercepted by Range No. V of the proposed canals. The area of the drainage crossed by this canal is not so extensive as in the case of Range No. IV, and the greater part of it was first accurately ascertained when the scheme for the extension of the proposed High Level Canal Range No. IV, between Bhuddruck and Balasore, was prepared two years ago. In the general index map of the proposed canals, as given in Sheet No. 1 of Book I of the accompanying drawings, I have shown the areas of the various drainages crossed by the Canal Range No. V. The principal drainages are those discharged by the Kansbans and the Talpudda nullahs. To the east of this range of canal extends a continuous line of sand ridge on the sea coast, similar to that on the coast to the east of Range No. IV. A regular survey of this ridge has been made from below the mouth of the Gummai khal up to the mouth of the Burrabullong River, below the station of Balasore. In Sheets Nos. 21 to 25 of Book I of the accompanying drawings, the survey and section of the different nullahs which intersect this ridge have been shown. From these it will be seen that the drainage intercepted by Range No. V is discharged under *exactly the same conditions* as that which crosses Ranges Nos. IVA and IVB canal, only in the former range the extent of the inundated country is not so large, nor is the area of the drainage basins so extensive. In the index map of Range No. V, as given in Sheet No. 5 of Book I of the accompanying drawings, I have shown as accurately as I can the extent of the inundated area of low tract on both sides of this range. There can be no doubt as to the extent of the low country between the line of the proposed canals and the said range on the coast. The area of the low country to the west of the canal has been shown as accurately as we could from the few lines of levels taken by us. It is not, however, necessary for our work to know the exact area of this tract above the canal line, as it will not help us in any way in determining the amount of waterway to be allowed across the canal. What we have to deal with principally is the area of the tract lying between the sand ridge on the coast and the line of the proposed canal.

53. The drainage intercepted by Range No. V of the proposed canal is proposed to be provided for by means of flood escapes, as well as inlet and outlet sluices, similar to those proposed for Ranges Nos. IVA and IVB of the projected canals. I will first take up the flood escapes. In determining on the length of the escapes I divide the canal into two parts as follows, *viz.*, the first part extending from the Burrabullong River to the ridge between the Kansbans and Talpudda nullahs; the second part between the ridge alluded to above and the Metai River. In the first part, to find the length of the escape, we have to ascertain, first, the discharge per second required to raise the flood level to its maximum height, from the time the inundation waters begin to spill over the country; second, the area of the country inundated between the line of the canal and the sand ridge on the coast. The time for the rise of the flood waters to the maximum height has from careful enquiries, as well as from actual observations made of the ordinary floods during the last monsoons, found to be from 36 to 24 hours. The area of the inundated country is about 10 square miles. In calculating the area I have not taken into account the country to the east of the canal from the 1st to the 5th mile, as this will be inundated by the spill waters of the Burrabullong River below the canal crossing. The average level of country between the line of canal and the sand ridge on the coast and

which is to be inundated being 111·00, and that of the highest flood waters 116·00 plus datum, the depth of the inundation waters will be about 5·00 feet over the country. To inundate 10 square miles of country to the extent of 5 feet in depth in the 24 hours, we will require a discharge of 1,614 × 10, or 16,140 cubic feet per second. To provide for this discharge across the canal, we have 3,000 lineal feet of flood-escapes, and 300 square feet waterway in the sluice opening in the portion of the canal between the Burrabullong River and the Talpudda nullah. The top of the flood escape being 111·50 plus datum, and the level of the highest flood being 116·00, the mean depth of the inundation waters flowing over the escape will therefore be $\frac{116{\cdot}00-111{\cdot}50}{2}$, or 2·25 feet. The mean flood area over the escape will therefore be 3,000 × 2·25, or 6,750 square feet. To this is to be added the area of the sluice openings, or 300 square feet, as stated above. The total flood area will therefore be 6,750 + 300, or 7,050 square feet. Allowing for a mean velocity of 2½ feet per second, this will give us a discharge of 17,625 cubic feet, or (say) in round numbers 18,000 cubic feet per second, against 16,000 cubic feet per second required to inundate to a depth of 5 feet the country between the line of the canal and the ridge on the sea coast. In addition to the surplus discharge of 2,000 cubic feet, we have to take into account the rainfall over the low tract itself, as well over 4 square miles of the high ridge to the south of the Talpudda nullah, and 3 square miles to the north of Prag nullah, and the drainage of which will also flow into this low tract. This will increase the surplus discharge by another 4,000 cubic feet per second, taking the flow-off of the rainfall to be nine inches in depth in the 24 hours; the surplus discharge will therefore be about 6,000 cubic feet per second, and is allowed to provide against the discharge of the Talpudda and Prag nullahs during the period of 24 hours that the low country between the sand ridge and the line of canal is being inundated to the extent of 5 feet in depth. The mean flood areas of these nullahs being only about 3,000 square feet, the discharge of 6,000 cubic feet per second ought to be sufficient, together with the spill waters of the Burrabullong River, which will during inundation flow into the Talpudda and Prag nullahs also.

54. The total area of the basin, for the drainage of which provision is proposed to be made in the canal for the discharge of 18,000 cubic feet per second, is 180 square miles. Calculating as accurately as we can with the information at our disposal, the area of the inundated low tract of country above or to the west of the canal is found to be about twice *as* that of the country to the east of the canal, and the depth of inundation to be about 4½ feet in this case; this will allow for a further mean discharge of 29,000 cubic feet per second from the same basin in the first 24 hours, so that the total discharge off the basin of 180 square miles is 47,000 cubic feet per second in the 24 hours, or at the rate of 255 cubic feet per second per square mile in the 24 hours. This permits of a flow-off of over 9½ inches in depth in the 24 hours, or what is about very likely to occur during the extraordinary rain storms which occasionally visit this coast.

55. Then, as regards the portion of the canal between the Kansbans and the Metai rivers. There being no ridge or watershed near the coast between these two rivers, the inundation waters of both the rivers are accumulated over the same low tract, and it is almost impossible to ascertain separately the exact area of the tracts flooded by each river. The Kansbans receives the drainage of 400 square miles by the time it crosses the line of the projected canal. The Metai is fed principally by the flood-waters of the Salundi River and by the drainage of the country between the Kansbans basin and the Salundi River; occasionally, during the extraordinary high floods, the spill waters of the Byturnee River also flow into the Metai below the proposed terminus of the canal. In fixing on the length of the flood escape we have, however, to deal only with the extent of the inundated area between the canal and sand ridge on the coast. This area is found to be about 6 square miles at the outside. The time required to inundate this area is found to be the same as for the Talpudda nullah, or about 24 hours. The average level of the inundated tract being 111·50 plus datum, and that of the flood waters of their maximum height being 116·00 plus datum, the depth of the inundation water over the country will be 4½ feet, and the discharge per second required to inundate it in the 24 hours will be 1,452 × 6, or 8,712 cubic feet per second. To provide for this, we have flood escapes to the extent of 3,000 lineal feet as follows, *viz.*, 2,000 lineal feet for the Kansbans and Sychunpore nullahs, and 1,000 lineal feet for the Gummai nullah. The top of the flood escape being at 111·50 plus datum, and the highest level of the inundation waters 116·00, the mean depth for calculating the flood area over the escapes will be $\frac{116{\cdot}00-111{\cdot}5}{2}$ or $\frac{4{\cdot}5}{2}$ or 2·25. The mean flood area over the proposed escapes will therefore be 3,000 × 225, or 6,750 square feet. In addition to this, we have 225 square feet of waterway in the outlet sluices and inlet sluices in this

portion of the canal, so that the total flood area provided across the canal in this part will be 6,750 plus 225, or 6,975, or (say) 7,000 superficial feet in round numbers. The mean velocity acros the canal being at the rate of 2½ feet per second, the discharge will be 17,500 cubic feet per second, being about 8,800 cubic feet in excess of that required to inundate the 6 square miles between the coast ridge and the line of canal. To this surplus discharge of 8,800 cubic feet per second is to be added the discharge due to the flow of nine inches of rainfall in the 24 hours over the 6 square miles or 6 x 242, or 1,452 cubic feet. So that the aggregated surplus discharge will be over 10,000 cubic feet per second, which will suffice for the mean discharge of the Gummai and Kansbans and Sychunpore nullahs during the 24 hours that the area of 6 square miles will be inundated to the depth of 4·5 feet.

56. For the portion between the Gummai nullah and the Metai River I have for the present allowed a flood escape of 1,000 feet in length. Probably this escape will, after further observation of the floods during the construction of the canal, be found to be unnecessary, as it is obvious that the larger the quantity of flood waters we divert into the Metai River above its junction with the projected canal, the greater are the probabilities of this river preserving its present deep and well-defined channel. The cost of this additional 1,000 feet of flood escape is not much, and it might be allowed to stand till we can from actual observation ascertain to what extent the country to the east of the portion of the canal between the Gummai nullah and Metai River is inundated from the flood waters of the Kansbans River. In case, however, the proposed flood escape be not required here, it is likely that in some other portion of the canal we may require an additional waterway, in either by flood escapes or sluices, so that the cost of the work will ultimately be utilized.

57. I will now compare the aggregate area of waterway allowed across the canal for the discharge of the maximum floods with the flood sectional area of the streams which intersect the ridge on the sea coast to the east of the canal. In the portion of the canal between the Burrabullong River and the Talpudda nullah, the total length of the flood escape is 3,000 lineal feet, and the depth of water over top of escape during highest floods being 4·5 feet, the flood or discharging area will be 4·5 x 3,000, or 13,500 square feet. In addition to this there are 12 vents in the outlet sluices for this portion of the canal. The area of each vent being about 25 square feet, the total sluice waterway will be 300 square feet. The agregate area of the waterway will therefore be 13,500 + 300 = 13,800, or (say) 1,400 square feet, and allowing for a mean velocity of 2½ feet per second through the above area, the total discharge across the canal will be 14,000 x 2½, or 35,000 cubic feet per second. The aggregate flood areas of the streams which intersect the ridge opposite to this portion of the canal is 10,163 square feet, as follows:—

The mean flood level of 114·00 plus datum, as assumed for the mean flood areas of the streams at their mouths, is rather high if we consider the rise and fall of the tides in the sea; but, to be on the safe side, and in the absence of actual observations, I have assumed a higher level in my calculations.

	Square feet.
Talpudda nullah	1,047
Flow over banks	218
Jamka nullah	1,344
Flow over banks	2,538
Moisali nullah	553
Soondra „	694
Flow between banks	3,769
Tot al .	10,163

Allowing for a mean velocity of 5 feet per second through the streams and 2 feet per second over their banks at their intersection by the sand ridge, we have a discharge of 31,240 cubic feet per second, or 3,760 cubic feet *less* than that provided across the canal. In assuming a mean velocity of five feet per second through the streams, we have allowed, if anything, *too much*; during the flood tides in the sea the discharge through these streams will be greatly retarded. However, as explained in paragraph 49 preceding, I have, in the absence of actual observations during extraordinary inundations, allowed for a greater discharge than what will probably be found to be necessary, so as to be on the safe side. If we compare the discharge of the 35,000 cubic feet per second, as provided for across the canal, with the area of the basin, the drainage of which is to be discharged, we find that it represents a flow-off of over seven inches in depth in the 24 hors. In paragraph 54

This does not take into consideration the fact of some portion of the Burrabullong River inundation waters being discharged through the Soondra and Moisali, &c., khals during extraordinary floods, and which must necessarily lessen the discharge from the basins of the Talpudda and Prag nullahs.

preceding it has been shown that we have provided for a discharge of 47,000 cubic feet per second, or equivalent to a flow off of over nine and a half inches in depth of the drainage basin in the first 24 hours of the rainfall before the flood waters rise to their maximum height, so that taking the two together, we provide for a flow-off of 16½ inches in depth of the drainage water in the first 48 hours of the commencement of the rain storm. This is not taking into consideration the large quantity which will still lie over the ground in the remainder of the basin. There can, therefore, be no doubt as to the sufficiency of the waterway proposed to be allowed across the line of canal.

58. In the portion of the canal between the Kansbans and the Metai River the waterway allowed is as follows, *viz.*—

Flood escapes	for the Luchimpore and Kansbans rivers	2,000
Ditto	for Gummai nullah	1,000
Ditto	between Gummai nullah and Metai River	1,000
	Total	4,000

The highest flood level and the level of the tops of the escapes being the same as for the Talpudda nullah, the area of the waterway during highest flood level over the escape will be 4,000 × 4·5, or 18,000 square feet. In the above calculations I have taken into account also flood escape between the Gummai and the Metai, as a portion of the inundation waters which pass over this escape can also be discharged through the Gummai nullah. To the area of waterway, as obtained above, is to be added the area of the outlet sluice vents nine in number and of the total area 225 square feet. To that the aggregate area of the waterway will be 18,225 square feet, and this with a mean velocity of 2½ feet per second will discharge 45,562 cubic feet per second. Now, the total flood area of the Kansbans, the Gummai, and the Sychunpore nullahs at their intersection by the sand ridge on the sea coast is as follows:—

The mean flood level of 114·00 plus datum, as assumed for the mean flood areas of the streams at their mouths, is rather high if we consider the rise and fall of the tides in the sea; but, to be on the safe side, and in the absence of actual observations, I have assumed a higher level in my calculations.

	Square feet.
Kansbans nullah channel	1,551
Flow over its banks	6,651
Sychunpore nullah channel	761
Flow over its banks	4,050
Gummai nullah channel	691
Flow over its banks	4,170
Total	17,874

Allowing for a mean velocity of 5 feet per second through channels and 1½ feet per second over the banks, the discharge through the above nullahs at their exits into the sea will be only 37,325 cubic feet per second, or 8,237 cubic feet per second less than that provided across the canal; but, then, it is to be remembered that a portion of the waters passed over by escape in the 31st mile of the canal will probably flow down into the Metai. Taking the maximum discharge across the canal as 45,562 cubic feet, and the area of the drainage basin as 400 square miles, the waterway provided for in the canal is sufficient to allow for a flow-off of over four inches in depth over the whole basin in the 24 hours. In paragraph 55 preceding it has been stated that the waterway across the canal provided for a discharge of 17,500 cubic feet per second for the first 24 hours of the rainfall; to this is to be added the discharge also over the last causeway between Gummai and Metai, or an additional discharge of 5,625 cubic feet per second at the usual mean velocity of 2½ feet per second. The aggregate discharge across the canal in the first 24 hours will therefore be 17,500 + 5,600, or 23,100 cubic feet per second; and that for the second 24 hours will be 45,562 cubic feet, and this will be equivalent to allowing for a flow-off of over six inches in depth in first 48 hours over the whole basin of 400 square miles after the commencement of the rain storms, leaving out of consideration the large quantity of inundation waters which will flow into the Metai River above junction of canal, and also that which will still lie over the low inundated tract of country to the west of the line of the proposed canals. The above calculations, as well as those given in paragraph 57 preceding, have been made on the assumption that the flood waters stand at their maximum height for 24 hours. From observations taken last monsoons, and from careful enquiries made by us, it appears that the

The flow over the banks in this case has been taken at 1½ feet per second, as there is much jungle on banks which must obstruct the velocity a good deal.

flood waters remain at the maximum height from 36 to 24 hours. I have taken the latter period for safety's sake; but even with this the velocity is not likely ever to be 2½ feet per second, the maximum assumed by me.

59. **Inlet Sluices, Range No. V.**—The inlet sluices for this range have been provided for discharging into the canal the ordinary local drainage, as well as for raising the canal waters to the level of the top of the escape before the inundation waters cross the canal. The ordinary heavy drainage will be passed over the canal by means of the proposed flood escapes. The inlet sluices will only be used for drainage purposes, when it is required to reduce the waters to below level of low country to the west of the canal. Comparing the level of the low country with the areas of the inlet sluices, it will be seen that the waterway allowed is more than sufficient. The following table gives the necessary information on this subject:—

Portion of Canal.	Area of low country to the west of the canal.	Area of waterway of inlet-sluices.	Area of waterway of inlet sluice per square mile of low country.
Canal from Burrabullong to Talpudda . .	20	14 × 25, or 350 sq. ft.	17
Canal between Kansbans and Metai . .	20	16 × 25, or 400 „	20

The proportion of 17 and 20 square feet of waterway to one square mile of low country to be drained will, with a mean velocity of 5 feet per second, allow for a flow-off of four inches in depth in the 24 hours, which will be more than sufficient.

60. The areas of the waterway required for the inlet sluices have been, however, fixed, with reference chiefly to the time required, to raise the canal water level to the top of the flood escapes. The level of the water in this range of canal will probably be reduced to 109 50 plus datum at the outside. The mean level of water in the canal will therefore be $\frac{111{\cdot}50+109{\cdot}50}{2}=$ 110·50 plus datum, and as the bed of the canal is to be at 101·00 plus datum, the mean depth of water in the canal will be 9·5 feet. The mean bottom width of the canal being 51·25 feet, and the ratio of the side slopes of the canal 1½ to 1, the mean width at surface of water will be 51·25 + 3 × 9·5, or 78·75 feet, the length of the canal being 38 miles. The total quantity of water required to raise the canal water surface from 109·50 plus datum to 111·50 will therefore be as follows:—

Length.		Mean width.		Cubic feet.
38 × 5,280	×	78·75	× 2, or	32,020,080

In this range, owing to the short length of the basins of the drainage intercepted by it, I have allowed only nine hours for the rasing of the canal waters to the requisite level of 111·50 plus datum. Then with the above data, the discharge per second required to raise the canal water from a level of 109·50 to 111·50 plus datum will be $\frac{32{,}020{,}080}{9\times60\times60}=995$ cubic feet. The level of the floors of the proposed slucies being at 107·00 plus datum, and the mean level of water in the canal being 110·50, and the width of the sluice vent 5 feet, the discharging area for each vent will therefore be 5 × 110·50—107·00 = 5 × 3·5, or 17·5 feet. Allowing for a mean velocity of 2½ feet per second, the discharge through each vent will be 43·75 cubic feet per second, and the total number of vents required will be $\frac{995}{43{\cdot}75}$, or 22·8, or (say) 23 in round numbers. I have allowed 30 vents, as in a long reach of canal, 38 miles in length, it is probable that the inlet sluices will not all be discharging at the same time or to the same extent. To be on the safe side, I have increased the number of vents by 30 per cent. over what is found to be necessary according to the calculations given above, or from 23 to 30 vents.

61. **Outlet Sluices. Ranges Nos. IVA, IVB and V**—The outlet sluices for the above ranges have been provided chiefly with a view of acting as supply sluices for taking in, during the dry season, the tidal waters required for the use of the canals, to recoup the loss due to lockage, &c. For drainage purposes one-half of the number as now provided will be more than sufficient. In Range No. IVA I have provided two outlet sluices, with eight vents in all. In addition to this there is to be a supply sluice of 10 vents similar to those proposed for Range No. III. This makes the total number of vents for supplying the canal amount to 18 openings. We can also, if necessary, utilise one or two of the inlet sluices in this range for supplying tidal waters required for the canal.

For reasons stated in paragraph 36 preceding, I have allowed a little in excess of the actual requirements of the sluices for the supply of the canal with tidal waters. In Range No. IVB I have allowed an outlet sluice of 10 vents and a supply sluice of 10 vents also. This makes 20 vents in all for the supply of this range, and is also probably in excess of the actual requirements. I have purposely proposed an outlet sluice for this range, instead of two supply sluices, as occasionally it will be necessary to reduce the level of the water in this range for the drainage of the country to the west of it. In Range No. V I have allowed 21 vents in the outlet sluices proposed for it. This is also probably in excess of the requirements of the canal; but for reasons given above, and as the cost of an additional vent or two of the proposed sluice is not much, it is better, I think, to provide in the beginning for a few vents in excess than to have to send in revised estimates afterwards. In this range the tides towards the Gummai and Kansbans are a little lower than in the Burrabullong and Panchpara rivers, and I have on that account also allowed for about 30 per cent. over the actual number required for the supply of the canal with tidal waters.

62. I now come to the description of the masonry works provided for the proposed canals. The principal masonry works provided for the proposed canals are the following, *viz.*—

Supply sluices.	Flood escapes.
Inlet sluices.	Locks.
Outlet sluices.	Inspection bungalows.

63. SUPPLY SLUICES.—The general plan for a 10-vent sluice is given in Sheet No. 1 of Book II of the accompanying drawings. The sluice, it will be seen, is similar in design to the ordinary drainage sluices in use in the tidal embankments in Hidgellee, with the exception that the position of the gates in the former are reversed. The self-acting gates, instead of being placed towards the river-side, face the canal, as the waters are to flow into the canal, and not out into the river. The self-acting gates will be of wrought-iron sheets, properly strengthened by means of T and angle iron. Cast-iron plates are to be let into the masonry for the self-acting gates to close against. The hanging gear of the self-acting gates to be on the same plan as that used in the drainage sluices in Hidgellee. The drop-gates on the riverside of the sluices will be only used in case any accident happen to the self-acting gates, or during storms and high tides in the river. I propose for the sake of economy to make these drop-gates of wood, as it will be so very seldom we will use these, and that during the rains, when the rivers are not so salt that the teredoes cannot possibly attack them. As explained in paragraph 36 preceeding, the level at which the tidal waters will be allowed to enter the canal can be easily regulated by letting down balk planks between the grooves for the drop-gates on the river-side of the sluice. There being little weight to be sustained by this sluice, and the greatest depth of water likely to flow over the sluice floor being only three feet, and that with a maximum velocity of 4 to 5 feet per second, I have not considered it necessary to allow any great depth of masonry for the floors of structure; the great desideratum in the masonry of a sluice, or any similar structure, is to have the work honestly executed, and with good materials; it is no use having the floor three and four feet thick if the materials used in its construction be bad, or the proportion of lime be short; considering the velocity through the sluice will not exceed 5 feet per second, the length of apron allowed is more than ample. To provide, however, against any unforeseen pooling in the bed of the channel in either side of the sluice, I have provided a row of sheet piling before the curtain walls in front of both the up as well as the down stream apron. The position of the proposed feeding sluice, with reference to the terminal lock, is shown in Sheet No. 2 of Book No. II of the accompanying drawings. The length of the channel between the sluice and the canal is about one quarter of a mile. This can, if considered necessary during construction, be slightly lengthened without adding much to the cost of the work.

64. INLET SLUICES, RANGE No. III.—The plan for this is given in Sheet No. 4 of Book No. II of the accompanying drawings. The sluice is on the same plan as the ordinary drainage sluice in the Hidgellee embankments, where the tides do not affect the discharge through the sluice. The sluice is to have only one set of gates worked by screw gearing. The gates to be of wrought-iron strengthened by T and angle iron, and to work in cast-iron grooves let into the sluice masonry. Grooves have been left in the opening of the sluice on the canal side to let in balk planks in case of any accident to the regular iron shutters, which have been placed on the other side of the sluice, so as not to interfere with the roadway across the sluice, and which is to serve as the tow-path. As these sluices will not be subject to the rise and fall of the tides, I have not provided any self-acting shutters for them. Screw gearing has been provided for the lifting and lowering of the shutters, as sometimes this will have to be done against a head of water during the monsoons; after once the shutters are lifted, for the entry of the drainage waters into the canal, it will not be necessary to lower them till the following November, unless there be such a long break in the rainfall as to necessitate the keeping in of the drainage waters for cultivation purposes. The maximum velocity per

second through the sluices will not exceed 5 feet, and will ordinarily be on the average about 2 to 3 feet per second, as by means of the shutters we can always regulate the head of waters flowing into the canal, and the drainage waters in the Doobdah jheel are accumulated very gradually. I have not therefore considered it necessary to provide any extensive apron for the sluices. The same remarks as those given for the supply sluices apply to the depth of the masonry in the floors of these sluices also. In addition to the regular apron in front of the sluices, I have provided for paving with dry brickwork the space left between the sluice, apron and the canal channel. The sluice has been placed 50 feet back from the general line of the side bank of the canal, so as to allow the drainage waters on entering the canal to spread over a large area, and thus have its velocity considerably reduced; any silt brought in will be probably deposited in the space between the canal and the sluices. As a further precautionary measure against the deposit of silt interfering with the depth of water required for purposes of navigation in the canal, the bed of canal immediately in front of the sluice, and for a distance of 100 feet on on each side of it, will be made three feet lower than its normal level. In addition to this, the bed of the channel leading the drainage water to the sluice will be made two feet lower than the sluice floor, so that any heavy silt which may be brought in by the drainage waters will be probably deposited in this lowered bed of the inlet channel before the waters enter the sluice. The floor-level of the sluice has been placed at 107·00 plus datum, or 2½ feet below the average level of the lowest land to be drained, and this will be quite ample for drainage purposes. The inlet sluices proposed to be erected in the side banks of the proposed supply channel from the Burtona sluice are of a simple description, as shown in the plan given in Sheet No. 3 of Book II of the accompanying drawings. These sluices will have not to be worked against any great head of water, and it is not therefore considered necessary to provide any screw lifting gear for the use of the shutter of these sluices.

65. Inlet Sluices for Ranges Nos. IV and V.—The plan for this is given in Sheet No. 5 of Book II of the accompanying drawings. These sluices are to be on the same plan as those for Range No. III, save that, instead of shutters worked by screw-power, we will have self-acting shutters fitted to the canal side of the sluice, to prevent the tidal waters of the canal during dry season from passing on to the low ground to the west of the canal, as well as to allow the drainage waters flowing into the canal, without any great head, as it is evident that with the self-acting shutters opening out towards the canal channel, there is nothing to prevent the drainage waters from flowing in and filling up the canal channel as soon as any portion of the drainage waters accumulated over the low lands to the west of the canal is not wanted for the purposes of cultivation, and is required to be discharged into the sea. The country through which Ranges Nos. IV and V pass has generally no protective works against the entry of the tidal water, either in the dry season or during the monsoons, since the tides here do not rise more than a few inches occasionally over the level of the country; but to avoid giving any cause for complaint against the canals, I have provided the inlet sluices with self-acting shutters on the canal side, as this will prevent the passage of the tidal waters out of the canal on to the fields to the west of it. The proposed lowering of the bed-level, both of the feeding channel above the sluice as well as of the canal bed in front of it, has been shewn in the plan of these sluices. The parapets of these sluices will be raised one foot above the highest flood-level, as there will be very little difference of level between the flood waters on the two sides of the sluice during the inundations. On the west side of the sluice grooves have been left at the opening for letting in balk planks whenever necessary, in case of any accident to the self-acting shutters or for any repairs to be done to the work.

66. Outlet Sluices, Range No. III.—The plan of this sluice is given in the same sheet as that for the inlet sluice for the same range. The sluice needs no particular remark, as it is on the same plan as the ordinary drainage sluices in Hidgellee. Precautionary measures have been taken against pooling of the channel bed below sluice by allowing sufficient length of apron, as well as providing a row of sheet piling in front of the lower curtain wall. The floor of the sluice has been made one foot lower than that of the inlet sluice, so as to allow of our reducing the canal water level sufficiently low to permit of a head of one foot, or mean velocity of 5 feet per second, to the drainage water entering the canal through the inlet sluice. The bed of the down-stream channel of the outlet sluices has been lowered, in order to obtain the requisite head of two feet, through the sluice vents, as explained in paragraph 39 preceding. The sluice has been fitted with iron shutters, worked by screw gearing. The shutters are to work in cast-iron grooves let into the sluice masonry; grooves have been also left on lower side of the sluice opening to let in balk planks, in case of any accident to the regular iron shutters.

67. Outlet Sluice, Ranges Nos. IV and V.—The general plan for these sluices is given in the same sheet as that of the proposed inlet sluices. The sluices for these two ranges are on the same plans as those for Range No. III, save that as they are to be utilized during the dry season as supply-sluices, it is necessary to fit the openings with self-acting shutters on the canal side, in addition to the usual shutters worked by screw-power on the sea side. During the dry season, when these sluices are used for feeding the canal with tidal waters, the shutters worked by screw gearing will be always kept lifted up to allow of the tidal waters freely entering the canal through the sluice. The self-acting gates on the canal side will prevent the outflow of the tidal water after once it has entered the canal. The floor-level of these sluices when used for supply purposes can also be regulated by letting balk planks in the grooves for the shutters on the sea side of the sluice as explained for the supply-sluices for Range No. III. During the monsoons, when the canals are to be fed by the drainage waters, the self-acting shutters on the canal side of these sluices will be removed, and the gates on sea side of the sluice lowered. The sluices, however, will during the monsoons be worked only for lowering the canal water-level whenever necessary for drainage purposes, or for the discharge of the flood waters during inundations, by means of the shutters on the sea side, and which are to be lifted and lowered by screw gearing.

68. Flood Escapes.—The plan for this work is given in Sheet No. 6 of Book II of the accompanying drawings. The proposed escapes are very simple in design, consisting chiefly of gaps left in the side banks of the canal, and with a metalled roadway, to serve as a tow-path across it, the crest level of the roadway in question being about the average level of the adjacent low country. The spoil in the part of the canal where the gaps are to be left will be thrown on either side of it. Aprons of sufficient width have been provided on the down-stream sides of these metalled tow-paths on both sides of the canal. The tow-paths, it will be seen from the plan of the work, are placed 50 feet from the edge of the canal channel excavation and on either side of it. As the level of the paved tow-paths is about 5 feet below that of regular embanked tow-path of the canal, the necessary steps have been provided to allow of the boatmen descending or ascending from one to the other, as the case may be. The ends of the side slopes of banks on both sides of the spaces which are to act as escapes across the canal are to be protected with dry brick paving, as shown on the plan of the work. In paragraphs 46, 57, and 58 preceding I have shown that the maximum velocity of the flood waters passing over these escapes can never exceed 2½ feet per second, whether at the commencement, when the flood waters first overtop the metalled tow-path of the escape, or when they are at their maximum height above it. The work as designed is capable of standing a much greater velocity than this, as has been ascertained from the experience gained from the effect of floods passing the causeways on the Cuttack Trunk Road, and other roads in Orissa, and with the fall of the country above the road, varying from 5 to 10 feet per mile. Moreover, on the proposed paved tow-path for the canal, there will be no traffic save that of the boatmen, and occasionally of a horse, when the inspecting officers go over the canal. To provide against the entry of silt into the canal over the tops of escape, it will be seen from the plan of the work that the up-stream side of the spaces which form the proposed escape, a trench about 3 feet deep is to be excavated. In addition to this the ground immediately next to the up-stream side of the paved tow-paths is lowered one foot so as to form also a silt trap as it were, and the canal bed also immediately in front of the escapes and for a couple of hundred feet on either side of it will be lowered two feet below the normal bed level of the range.

69. Locks.—The designs for the proposed locks have been given in Sheets Nos. 7, 8, 9, and 10 of Book II of the accompanying drawings. In the statement marked H, I have given the levels of the sills, copings, &c., and also the principal dimensions of the proposed locks on each of the different Rivers to be connected by the projected canals. No separate plan has been given for the locks on the Burrabullong River, as the locks on this river will be of very nearly the same size and dimension as that on the Metai River,—*vide* the statement alluded to above. The propesed locks are on the same plan as those already constructed for the tidal reaches of the canal in use in the Midnapore and Hidgellee districts, but with the following additions and alterations, *viz.* —

1st.—The wing walls, instead of being perpendicular to the longitudinal axis of the lock, have been placed slightly inclined to it, at an angle of about 45.°

2nd.—The feeding sluices, instead of discharging through a couple of large openings under the upper sill or in the chamber wall, have the tunnels taken right along the whole length of the chamber wall and the waters discharged through a number of small openings.

3rd.—The locks are to be placed at a distance of 150 feet from the edge of the river bank, with dwarf retaining walls on either side of the approach channel between the river and the lock.

4th.—The gates to be all of wood covered with copper sheathing.

5th.—" Porte valets " have been provided for both upper and lower gates, to prevent the entry fthe tidal waters of the river through the lock.

6th.—Wooden sill beams have been placed in both sills, between the gates and the stone sills.

7th.—Culvert openings at the upper and lower sills are to be provided with two sets of shutters—one on the face of the vent, and the other in the opening inside the counterfort.

8th.—No valves have been provided in the lower gates for the emptying of the chambers, which is to be done by feeding sluice, with the requisite shutters, to be also provided through the counterforts in the lower bay of the lock.

70. I will now proceed to state my reason for the changes proposed in the designs for the locks.

First, with reference to the alteration in the inclination of the wing walls to the lock. This has been made chiefly for the convenience of the boat traffic, so as to bring the end of the lock wing walls in a line with the general direction of the canal tow-path. With the locks as at present designed, with wing walls at right angles to the lock, the men employed in towing lose all control over the boats just at the very place where they should have it, in order to prevent the boats from striking against the lock gates, &c. On referring to the designs of the proposed locks it will be at once apparent that this inconvenience will be avoided by the proposed change in the direction of the wing wall. Wing walls placed at right angles to the axis of the lock act, I think, injuriously on the structure, as any settlement of these walls either causes an ugly crack at their junction with the counterforts, or helps as it were the settlement outwards of the chamber walls and counterfort, which generally leads to the unseemingly longitudinal cracks from sill to sill and along the invert of the lock. The change in the feeding sluice has been made for obvious reasons, *viz.*, to reduce the velocity of the waters entering the chamber, and thus prevent any damage to the boats passing through the lock.

71. To avoid the heavy expenses incidental to removal of silt, required for keeping open for navigation purposes the channel between the river and lock, it is proposed to limit the distance between the two to 150 feet, *i.e.*, from the top edge of the side slope of the river bank to the end of the lower bay walls or the commencement of the wing walls. Dwarf retaining walls are to be constructed on either side of this channel between the river and the lock. The dwarf walls are to have openings on the top, with intervening piers, which are to have grooves for letting in gates, to keep back the silt deposited at the back of these walls and between it and the top edge of the side slope of the channel from sliding into the bed of the channel. Of the total length of 150 feet between the river and the lock, 50 feet, consisting of the masonry apron, will be kept clear of silt by the flow of the water through the emptying sluice in the lower bay of the lock. For the clearance of silt in the bed of the channel, between the dwarf walls, it will be only necessary to employ a small steam-scraper, to stir up the silt, and drag it out into the deep channel of the river in front of the lock, and where it is sure to be carried away by the tidal currents. For the removal of silt deposited behind the dwarf wall and on the channel side slope above it, it is proposed to employ manual labour whenever the silt will be *dry* enough to admit of its removal in baskets, if not mud barges can during low water be taken alongside of the dwarf walls and the silt accumulated behind the walls, &c., scraped on to the barges through the openings left on the tops of the walls, and alluded to above. Looking at the plans of the proposed locks, the advantage of having the dwarf retaining walls will be at once apparent Without these walls all the silt deposited over the side slopes of the channel would gradually slide down into its bed and fill it up; whereas now the only silt which can possibly be deposited will be that due to the tidal waters which lie *immediately* over the bed itself, or (say) for 40 feet in width. Without the dwarf walls, supposing the tidal waters during flood tides stand to a depth of 20 feet over bed of approach channel, and that the rates of side slopes of the channel be only 2 to 1, then the surface width of the channel at high water would be 40 × 4 × 20, or 120 feet; or, in other words, the silt deposited over the channel bed would be from a width of the tidal waters of 120 feet instead of the 40 feet only, aswith the proposed dwarf walls. But, again, it is to be remembered that the deposit of silt from the tidal waters depends on the depth of waters, and as the depth

of water over the side slopes will vary from 20 feet to *nil*, virtually without the dwarf wall the silt deposited would be from that due to a width of 80 feet; or, in other words, the provision of the dwarf walls in the lock will reduce by at least *one-half* the deposit of the silt over the bed of the approach channel between the lock and the river.

72. From the experience we have had already with the iron gates in use in the tidal canal in the Midnapore and Hidgellee districts, it is not considered advisable to have any more gates of iron, as their cost in this country is excessive, and it is difficult to prevent the oxidation of the iron in the gates when exposed alternately to the action of the air and of the salt-water of the tides. The timber gates will be lighter and cheaper, and will, it is believed, ultimately with proper care last almost as long as the iron ones. To preserve the woodwork of the gates against the ravages of the teredoes, it is proposed to cover gates on both sides with sheet copper to one foot above highest salt tidal water level. The frame-work of the gates will be of teak, and the planking of black sissoo, which can be obtained in large quantities in the hill tracts of Orissa. Sissoo is a more lasting and heavier timber than teak, and will besides be cheaper. I would have proposed to have had the frame-work of the gate of sâl, but at present it is doubtful if properly seasoned sâl can be got from the hill tracts in time for our work. There is plenty of splendid sâl timber in the hill tracts, but the great difficulty is the seasoning, and our work could not afford to wait for this. In after years sâl can be used when the gates have to be renewed. As there are to be only two pairs of gates in each lock, and both opening towards the canal, the provision of "porte valets" was considered necessary in order to prevent the tidal waters from feeding into the canals through the locks. The wooden beams in the sills have been provided with a view to prevent as much as possible any unnecessary leakage between the gates and the stone sills, and also because these beams act as buffers as it were between the gates and the stone sills, and thus afford considerable protection to the latter.

73. The lock will have to be occasionally worked when the waters in the rivers are on higher level than the canal water surface. To prevent the entry of the tidal water on these occasions the feeding culvert openings in both the sills have been provided with two sets of shutters, one of the *face* of the vents towards the sills, and worked with the usual rack-and-pinion gearing and balance buckets; and the other shutter in the opening inside the counterforts, just below the whole for the balance bucket. The latter shutter will be very seldom used, especially in the upper sill culverts. I have preferred to have two sets of shutters at a little higher cost than to have only one shutter working in a regular groove, so as to withstand the pressure of the waters from both sides. These shutters, it is to be remembered, will always be under level of water surface, and should they get clogged at any time by a falling piece of brick or stone, it will render the lock quite *useless*, and stop all traffic through it till the shutters could be set right again. This will always be a matter difficult and expensive, as the work will have to be done under water. Shutters designed to work on the face of a sluice opening and to withstand the pressure of water only in front, cannot possibly get out of order as those working in a regular groove on each side. For the emptying of the chamber I have provided culverts through the lower bay counterfort in lieu of valves in the lower gates. This can be done without adding much to the cost of the work, and in my opinion it is a better arrangement than having valves in the gates in such remote localities as the sites of the proposed locks. I think it will be more convenient and economical to have the gates, &c., as simple in construction as possible. To provide valves in the gates only complicates their construction. Moreover, the culvert sectional area is about one and a half times that usually provided for in the valves in the gates. The area of each valve in each leaf of the gates is about 12 square feet, or 24 square feet in the pair; whilst the area of the culvert opening is about 36 square feet.

74. To provide against unequal settlement the widths of the foundation of the locks have been made as wide as possible, and a row of sheet piling is to be driven in all round the foundation pit to form, as it were, a casing for the concrete bed of the foundation. In addition to this it is proposed to insert longitudinally hoop iron in the brick masonry of the lock chamber wall, counterfort, and wing walls. This was done in all the locks constructed in Hidgellee, and it is believed it effectually prevents any transverse crack in these walls. It is hoped that the precautionary works, as proposed above, will prevent the longitudinal cracks which have hitherto occurred in the sills and inverts of the existing tidal locks, both in the Cuttack District, as well as in Midnapore and Hidgellee. After all, these cracks are very slight, and do not in any way affect the stability of the structures. The cracks generally close in after a year or so, as soon as the earth forming the filling in begins to exert the proper pressure against the chamber walls, &c. It is the want of pressure from the newly-filled up earth which

is one of the chief causes of the cracks in the sills, &c., walls settling outward away from the longitudinal axis of the lock.

75. The coping of the lock walls have been raised everywhere a foot above the highest flood level. In the lock on the Bagda River, however, the upper bay is only raised above the highest cyclone flood level, and the chamber wall and lower bay counterfort will be liable to be submerged during cyclone waves, but this will be to a depth of two or three feet only, and that for about four or five hours in about once in 30 or 40 years, and this will not cause any harm to the structure. During the cyclone of October 1874 the Kaleenuggur lock was bodily submerged to the extent of *four* feet of water over coping level, and was not injured to the slightest extent. There is, therefore, no reason why we should anticipate any damage in the case of the proposed lock on the Bagda River, specially as in the case of this lock there will be no rush of water over it, as was the case in the Kaleenuggur lock, when in 1874 the cyclone-wave went over it and inundated the whole of Range No. II canal, *seventeen* miles in length In the lock on the Suburnrekha River the lower bay counterforts have been raised above highest level. The chamber wall and lower bay counterforts are raised only about the highest ordinary floods. This will not allow of the lock being used when the flood waters rise over 118·00 plus datum. But then these extraordinary floods only happen once in eight or ten years, and when this will happen, the traffic across the river is sure to be stopped for a day or so, as it would not be safe for boats, even if propelled by steam-power, to venture across the river during such high floods. There will, therefore, be no advantage in unnecessarily increasing the cost of the locks by raising the chamber walls and upper bay counterforts to the same level as the lower bay counterforts. After all, the stoppage of the traffic for a day or so in eight or 10 years is not a matter of such consequence as to necessitate the additional expenditure required for raising all the lock walls above the level of the extraordinary floods. The locks on the Panchpara, the Burrabullong, and the Metai rivers have the coping of all the walls one foot above the highest flood level.

76. The hollow quoins and sills of the locks are to be of artificial stone on Coignet's patent, which has been used successfully in the locks on the Hidgellee canals, and found to save a great deal of labour and delay, especially in the dressing of the hollow quoins when hanging the gates in the locks. The coping over the counterforts will also be of stone. This will be of artificial stone, which can be manufactured *in situ* in a monolith as it were, and this will be of great advantage as a holding material for the anchor iron of the gates. For the sake of economy, the coping over the chamber walls and wing walls is to be of brick masonry, specially picked bricks being set on edge in cement mortar with rubbed joints. This will be quite strong for the traffic it will be exposed to. Afterwards, when the traffic in the canal increases, we can, if necessary, replace the brickwork with artificial stone or laterite, as may be considered expedient.

77. The mean section of the chamber walls is generally about ·40 of the height of earth-filling at their back, and of the wing walls from ·33 to ·30 of the height. The section given to the dwarf walls provides against the surcharged pressure against it, and varies from ·33 to ·40 of the height for a surcharged wall, according as we suppose the silt to be accumulated against it, to the very top, or 10 feet above level of channel bed, or one foot below it, as will usually be the case before it is removed. In the following table I have shown in detail the width of the chamber walls of all the locks as compared with the height of filling in at their back :—

NAME OF LOCK.	Height of chamber wall.	Mean width of chamber wall.	Height of earth-filling in at back of chamber wall.	Mean width of wall up to level of earth-filling in at back of chamber walls.	PROPORTION BETWEEN MEAN WIDTH AND HEIGHT OF WALL.	
					For full height of wall.	For height of wall up to filling-in earth at back.
	Feet.	Feet.	Feet.	Feet.		
Bagda River	21	7·7795	20	7·966	·37045	·3983
Suburnrekha River	20	7·8205	19	8·0194	·39102	·4221
Panchpara „	25	8·6844	23	9·0843	·34738	·39497
Burrabullong and Metai rivers .	21	7·7795	19½	8·0579	·37045	·4132

In calculating the mean width of the walls, as given above, and as also shown in the lock drawings, the necessary deduction for the culvert openings in the walls has been made. The mean width of the wing walls are also shown in the lock drawings.

78. I have not provided for any bridge over the locks, as the line of canal is taken generally *so close* to the coast that it intersects very little cross-country traffic, and bridges on a line of purely navigable canals are a source of much *inconvenience* and cause of *much unnecessary obstruction* and *delay* to the boat traffic through the canal. Any cross-country traffic intercepted over the proposed canals will be provided for by ferries which will be treated of further on when discussing the question of overbridges for the proposed canals.

79. BUILDINGS.—The permanent buildings proposed for the projected canals is only an inspection bungalow of the second class, which is proposed to be constructed in the centre of Range No. V, for the accommodation of the subordinate who will be placed in charge of the range after construction. For the other two ranges there are already inspection bungalows connected with the Government embankments, and these can be used by the canal officers and subordinates. For Range No. III the following inspection bungalows in Hidgellee will be available, *viz.*, Baithwore on the Surpai River, Heeraconea on the sand ridge at its intersection by the Peechabunee khal, and Bhograi on the Suburnrekha. For Range No. IV the bungalows at Balliapal on the Suburnrekha, and at Panchpara on the Panchpara River, will be available. The plan of the proposed inspection bungalow for Range No. V is given in Sheet No. 11 of Book No. 2 of the accompanying drawings. It will be observed from the plan that both the bungalow and its out-offices are to have flat terraced roofs. This description of bungalow on this coast, which, so much subject to high winds, &c., is by far more economical, as the cost of maintenance is much less, though its original cost may be a little more than of that of thatched or tiled roofed bungalows. Provision has been made in the estimate for the construction of temporary shelter sheds for the use of the working staff during the construction of the canals. The materials of these shelter sheds can, on the completion of the canal, be utilized for the construction of temporary toll offices and khallasies' huts at the lock sites for the lock establishment. The labour required for the construction of these temporary offices, &c., will not be much, and will be met with from the lock estimate contingencies, as was done in the case of the Hidgellee canal locks. This is more economical and more expedient than at the commencement of a work to construct *expensive* buildings and unnecessarily increase the charges for interest. Afterwards, when the traffic is well developed, the permanent buildings can, if considered necessary, be constructed. If the working of the proposed canal were left to me, I would arrange that the men employed in working the locks should keep their own sheds in order, Government of course supplying the necessary materials annually. This will keep down the cost of the maintenance of these sheds, and there is no reason why with proper management this should not be carried out everywhere.

80. In the general estimates for the canals I have included a sum of R15,000 for the construction of a store-godown and offices at Balasore, which will be the head-quarters of a division when the canals are constructed; and we will therefore require a godown to keep the various descriptions of stores required for the maintenance of the canals. For this purpose we must either build a godown or hire one in the town; and it is obvious that it will be more economical to build a godown, once for all, and save the cost of the rent. For the same reason it is proposed to construct a building for the accommodation of the office of the Executive Engineer in charge of the whole line from Calcutta to the Metai, and whose head-quarters will be probably at Balasore. The necessary plans and estimates, both for the office as well as the godown, will be submitted if the proposal be approved of, and the amount of R15,000 now included in the general estimates of the canal be sanctioned.

81. PROTECTIVE WORKS.—The protection against floods required for Ranges Nos. III and IV, as explained in the preceding paragraph, has been provided for by raising the canal side bank wherever necessary. In Range No. V this has also been done; but, for protection against flood waters of the Burrabullong River, it is proposed to raise above flood-level only the eastern side bank of the canal for the first three miles, and to construct a line of embankment on the right bank of the river, above the canal and between its northern terminus at Chargatchea and the Gubgaon village above it. The necessary detailed plans and sections for this work are given in Sheet No. 18 of Book No. I of the accompanying drawings. The work needs no special remarks, and the line of the proposed embankment has been kept as near the river as possible, so as to avoid the low ground beyond. The line will not interfere with the waterway of the river, as it will only throw into the river channel the small quantity which now spills over its right bank on to low country between the canal line and the high lands above it. The area of this is one square mile, and the average depth of inundation over it four feet, so that the interference of the proposed line of embankment with the river flood discharge will be scarcely felt, either to raise its level, or to cause any damage to the low land

below the canal, especially as these lands are all covered with jungle and not used for cultivation purposes. As the line of the proposed embankment will shut out the flood waters from the west side of the canal, all the spoil obtained from its excavation of the first three miles of the canal channel, save that required for forming the tow-path bank on its west side, will be utilized to raise above flood-level the side bank of the canal on the east side. So that the canal will thus be effectually protected against the inundation waters of the Burrabullong River, and which do not affect the proposed canal Range No. V beyond the first three miles of its length.

82. I now come to the question of overbridges across the proposed canals, for the accommodation of the cross-country traffic intercepted by it. The only road of any importance crossed by the line of the proposed canal is that connecting Contai in Hidgellee with Cuttack Trunk Road, and known as the "Contai and Belda" Road, and is intersected by Range No. III at the 10th mile of its length. There is very little or no traffic on this road. The only cart traffic on the road is during the cold season, when the Government officials come from Midnapore on tour; then it is only the carts belonging to the camps of the official which frequent this road. Contai being connected with Calcutta as well as with Midnapore by means of water communication available during all the year round, it is not likely that any goods would be conveyed by cart along this road. When the projected canals are completed, the facilities of water communication will be greatly increased, and there will, if anything, be less traffic on the road. I do not see any necessity of constructing an expensive overbridge on account of this road, and that just for the convenience of a few passengers and half a dozen carts in the year. It is not so much to the unnecessary cost of constructing an overbridge that I object, as the great inconvenience caused by it to the boat traffic in the canal. In a line of canal like that proposed, and where the boat will be propelled chiefly by the force of the wind, it is very necessary that we should disallow any work on the canal which is likely to cause only such obstruction on the canal as will necessitate the sails and the masts of the boats being taken down and put up every now and again as an overbridge is to be passed. We might as well expect the railway to provide overbridges at every line of communication intersected by it. Moreover, from the index map of the different ranges it will be seen that the cross-country traffic intersected by the canal is *very little.* In Range No. V there is only *one* or *two* villages between the coast and the canal. In Range No. IV the only villages of importance are Sartha and Bullong, and those on the eastern border of the Soolsa Pat. In Range No. III the lines of canal passes further from the coast line than in the case of the other two ranges; but even here the cross-country traffic is not much.

83. For reasons given in the preceding paragraph, I have not provided for any overbridge across the canal. In lieu of these bridges, ferry boats will be provided wherever necessary, both for intersection of the Contai and Belda Road, as well as for the cross-country traffic along the line of all the ranges. The cost of ferry-boats will be provided for from the amount included in the estimate under the head of "Tools and Plant." The boats will be made of sâl timber, which is cheap and plentiful in Balasore. For protection against teredoes, the bottom. of the boats will be covered with metal sheathing either of muntz or yellow metal or zinc I may as well mention here that in Ranges Nos. I and II of the existing canal in Hidgellee, ferry-boats have been provided in lieu of overbridges without causing any inconvenience or obstruction either to the cross-country traffic or to that on the road between "Contai and Tumlook."

84. RATES OF WORK.—In the detailed statement of the rates for the principal description of masonry works in the proposed canals, I have given all the information necessary to enable one to check the accuracy of the rates assumed by me in the different estimates. The cost of the masonry depends *chiefly* on the rates of fuel required to burn the bricks and lime. For the locks masonry, it is proposed to use only coal as fuel, as the works have to be completed in too short a period to allow of our procuring the large quantity of wood-fuel which would be required for each lock. Moreover, the outturn of *really well-burnt* bricks is very uncertain from kilns burnt with wood-fuel, especially on this coast, where it is very seldom that we do not generally have high winds from one quarter or the other. The rates of coal fuel assumed by me in my calculations vary from seven annas per maund on the Bagda River, to 13 annas a maund on the Metai River. The coal will have to be conveyed in native boats to the Bagda River, to the Suburnrekha River partly by boats and partly by sloops, and to the other river by sloops only. In calculating the rates I have assumed the price of rubble coal fit for brick-burning purposes to be in Calcutta three and a half annas per maund, or about Rs. 6

per ton. To this is to be added the cost of conveyance and insurance charges and profits of contractor, &c. For instance, for Burrabullong River, I have allowed 12 annas per maund, or Rs. 20-4 per ton, as follows, *viz.*—

	R	*a.*	*p.*
Cost of coal in Calcutta per ton at 3½ annas per maund	6	0	0
Conveyance charges, &c., including insurance risk as per paragraph 28 of the trade report of Orissa as submitted with this office No. 59 of 19th June 1877 .	11	0	0
Contractor's profit, &c.	3	4	0
Total . .	20	4	0

The rates for the other ranges have been similarly calculated.

85. For the sluices and flood escape, &c., it is proposed to use wood-fuel, as no very large quantity will be required for these works, which besides are so well scattered over the whole length of the proposed canals as not to necessitate the collection of wood-fuel in any large quantity at any one place.

86. The rates of ghooting limestone have been fixed with reference to the position of the quarries to the different works. In the detailed statement of rates it will be seen provision has been made for the grinding of the mortar to be used on the masonry works. It is proposed to have the lime and soorkee ground and made as *fine* as *possible* by steam-mills, and then mixed with the required proportion of sand, and again ground together in the ordinary mortar-mills of stone rollers, worked by cattle-power. The proportion of the mortar to by used on the works is 16 of lime to 12 parts of soorkee and 14 parts of coarse, clean sand. I have purposely used a small proportion of soorkee in the mortar, as this makes it finer and more impervious to the action of water through the mortar joints. Provision has also been made to point the mortar joints at the back of the chamber walls, &c., to prevent any leakage through the walls. It is also proposed to use cement in the mortar for pointing of the masonry joints on the face of the walls. It is intended to face all the masonry works, especially of the locks, with *jhama* or *clinker* bricks, as this will make the masonry quite safe against any bad effect of its alternate exposure to air and to immersion in salt tides; and, in fact, as far as the action of salt water is concerned, the clinker bricks will answer *much better*, in my opinion, than even sand-stone or laterite. In one of the Hidgellee canal locks all the stretcher bricks of the face of the masonry of the chamber walls, &c., are of clinker bricks, which have stood remarkably *uninjured*, either by traffic or from the action of salt water, &c.

87. The proportion of mortar for the artificial stone is the same as that used for the stones made in the Hidgellee canal locks and some of the Midnapore canal locks also. The stone is proposed to be manufactured by us after payment of the usual royalty to the patentee if required.

88. The rates for gates, culvert valves, &c., have been fixed, from what similar works on the Midnapore and Orissa canals have actually cost. The culvert valves, &c., will all very probably be made up in the Cuttack workshop, the rates of which have accordingly been assumed after careful comparison with the *actual* cost of similar works elsewhere. I have allowed Rs. 12 per square foot for the gates, as this is about what the timber gates actually cost in the existing canals. It is, however, possible that this rate might be somewhat reduced if timely arrangements could be made to get our supply of teak timber *direct* from Burmah to Balasore, instead of purchasing it in the Calcutta market. As there is no certainty when the proposed works will be sanctioned, I have thought it best to assume the same rate as what the similar works have actually cost in the existing canals in Orissa and Midnapore. The rates for the other items of the masonry works need no special remarks.

89. I now come to the rates allowed for the earthwork in the excavation of the canal channel, and these are as follows, *viz.*—

RANGE No. III.—R3 per 1,000 cubic feet with 5 per cent. for contingencies and 10 per cent. for maintenance during construction.

RANGE No. IVA.—R3-4 per 1,000 cubic feet with 10 per cent. for contingencies and 10 per cent. for maintenance during construction.

RANGE No. IVB.—R3-6 per 1,000 cubic feet with 10 per cent. for contingencies and 10 per cent. for maintenance during construction.

RANGE No. V.—R3-4 per 1,000 cubic feet with 10 per cent. for contingencies and 10 per cent. for maintenance during construction.

Virtually the total rates will be as follows :—

			Cubic feet.
Range No. III	3·45	per	1,000
„ No. IVA	3·90	„	1,000
„ No. IVB	4·05	„	1,000
„ No. V	3·90	„	1,000
Total	15·30	„	4,000
Average rate	3·82	„	1,000

The average depth of cutting and mean bottom widths in the several ranges is as follows *viz.*—

NAME OF RANGE.	CANAL WITH 40 FEET AS MINIMUM BOTTOM WIDTH OF CHANNEL.		CANAL WITH 50 FEET AS MINIMUM BOTTOM WIDTH OF CHANNEL.	
	Mean bottom width.	Mean depth of cutting.	Mean bottom width.	Mean depth of cutting.
	Feet.	Feet.	Feet.	Feet.
Range No. III	50·00	8·83	56·00	8·83
„ No. IVA	56·08	11·31	56·08	11·31
„ No. IVB	40·00	13·22	5 ·00	13·22
„ No. V	43·30	10·38	51·25	10·38

90. The rates allowed by me have been assumed after very careful local enquiries and after taking into consideration the nature of the soil, the depths of cuttings, &c., and the sources of the local labour market, along the different ranges of the proposed canal. The rates allowed in the estimates are almost 50 per cent. in excess of what similar works in Hidgellee cost when I had charge of them some five or six years ago, and since then the rates of earthwork do not seem to have increased, as they are still paying the *very* same rates for repair works as those which were prevalent during my incumbency. The extension of the Hidgellee Canal Range No. I to Gowakhally cost only R2·62 per 1,000 cubic feet, *inclusive* of all contingencies, &c., and this was done chiefly by labour imported from South Hidgellee, where it would have only cost about R2 per 1,000 cubic feet. Then, again, the new alignment of the embankments in Bhograi of the average height of 14 feet, and with earth taken from *one* side of the line only, cost R2·10 per 1,000 cubic feet, inclusive of all contingencies. The earthwork in the great sea dyke only cost R2·60 per 1,000 cubic feet, and the banks vary in height from 16 to 18 feet in height with an average base of 130 to 140 in width, and the greater part of the earth was thrown on the upper part of the bank, as the work consisted chiefly in raising the existing embankment. In addition to this disadvantage; the excavation pits on the seaside were liable to be submerged by the flood tides of the springs. Yet, in spite of all these difficulties, the work cost only about R2·600 per 1,000 cubic feet, and was completed only about six years ago. The rates of earthwork for its repairs is now only R2 per 1,000 cubic feet.

91. In determining upon the earthwork rates for the proposed canal, we have to take into account *the important fact* that we provide work for the men at their *very doors* as it were, and that there is no other work in progress at present in the district from which we could entertain any fear of competition. From the index maps of the different ranges it will be seen that the line of the proposed canal passes generally through a highly-cultivated country, with numerous large villages near to it. The principal inhabitants of these villages are of the class who used

formerly to manufacture salt for Government, and who are now only too glad to get some employment near their homes. To show how anxious the people are to get employment on the canal works, I may as well mention that this year the men employed in manufacturing salt for the merchants of Balasore, along the line of Range No. V, absolutely refused to take any advances for salt till all hope of getting work on the projected canal was over. Several of the headmen came to the subordinate stationed on the line of this range to watch the inundation, and offered to undertake works on the canal. This was the range in which I was gravely informed in 1874 that no labour was to be procured for the sake of love or money, and that it was all covered with jungle, &c.

92. Then, again, fears have been entertained that the excavations would be filled up by the overflow of the tides in the dry season, and of the inundation waters in the monsoons. Now, as regards the overflow of the tides. In Range No. III the only portion which will be subject to this contingency will be the first 7 miles, but the tides here do not rise more than one foot or two above the ground level, and can be easily kept out of the canal channel. If we were with lower rates able to work the excavation pits, varying from 5 to 8 feet in depth, for the sea dyke right on the sea coast, I see *no reason* why these 7 miles of the projected canal, with comparatively speaking much higher rates, should be *so very difficult* to excavate. The other portion of this range, as well as of the Ranges Nos. IV and V, will either be within the area protected by the Government embankments, or we will have to provide against only a possible overflow of five inches to six inches during the spring tides. As for leakage of the tidal waters into the canal channel, this will not be the case as far as our experience goes. Some of the lock foundation pits in Hidgellee were sunk 24 to 30 feet below country level, and eight to 10 feet below lowest water level of the river, without our being troubled with any water, either from spring or leakage from the sides of the pit. We have had besides no trouble from leakage in the excavation pits of the sea dyke or of the canal in Hidgellee. The soil along the projected canal is, if anything, much stiffer and more impervious to the leakage of the tidal waters than in Hidgellee generally. We are able to sink on this coast pits 10 feet deep vertically, and then no water is met with, nor have the sides of the pit slipped in.

93. Now, as regards the liability of the canal channel being swamped by the inundation waters during construction. In Range No. III the only portion which will be subject to the flood waters during construction is the portion from the intersection by the canal of the Jookee cross embankment to that of the Bhograi embankment, or from the 21½ mile to the 26th mile, or about 5½ miles in length. With the enormous amount of labour available in this part of the district there will be no difficulty in raising above flood level in one season the flood side bank of these 5½ miles of the canal. Then, as regards the portions of the canal in Ranges Nos. IV and V, I cannot understand why any difficulty should be anticipated, if ordinary precautionary measures be taken when executing the work. It is not to be supposed that in executing a line of canals like that projected we would commence the work everywhere at haphazard, and adopt to preventive measures against possible damages by the inundation water during construction. The excavation of the canal channel could be so arranged that no length of canal would be commenced the side banks of which could not be raised in one season sufficiently high to keep out inundation waters. Cross dams could be easily thrown up at each end of the completed portion of the canal as protection against inundation waters. Any water collected in the canal excavation during the rains can always be easily drained off at the commencement of the working season by the numerous tidal creeks which intersect the line of the proposed canal. Considering that the bed level of the proposed canal is about 4 to 5 feet above lowest water level of the tides, there should be no difficulty in draining off, whenever necessary, the water which may accumulate in the canal channel at any time during the period of its construction.

94. The percentage for contingencies and maintenance, as allowed in the estimate, will be more than ample to provide for drainage, excavation of silt, and construction of protective cross bunds, &c., &c., during construction. The actual rate allowed for earthwork includes all charges for tools and plant and for hutting of coolies, &c. Of the latter work very little will be necessary, as the imported labour will not be much, and wherever used will generally find shelter in the adjacent villages with their fellow-castemen. It is not usual, either in Hidgellee or here, for Government to supply picks, kodals, &c., to the earthwork coolies, as this only leads to unnecessary expenditure in the purchase of tools, and afterwards entails a great deal of labour on the working staff in recovering the tools from the contractors on the completion of the work.

95. From the facts stated in the preceding paragraphs, it will be seen that the rates for earthwork, as allowed by me in the accompanying estimates, is *more than sufficient*. In fact, I have allowed for a little higher amount than what the work will probably cost, and if I have the superintendence of the work, I fully expect to be able to effect some saving in the earthwork estimates. The average rates allowed by me comes up to R3,825 per 1,000 cubic feet, inclusive of all contingencies, &c., as stated in paragraph 89 preceding, and this is about ·50 of a rupee only per 1,000 cubic feet *less than* what Mr. Walker, in his letter No. 544 of the 16th March last, recommended should be allowed for the earthwork of the projected canal. The rates, including contingencies, proposed by Mr. Walker were as follows, *viz.* —

	R		Cubic feet.
Range No. III	4·29	per	1,000
„ No. IV	4·29	„	1,000
„ No. V	4·40	„	1,000
Total . .	12·98	„	3,000
Average . .	4·33	„	1,000

Mr. Walker, in proposing the above rates, went unfortunately on the assumption that the country through which the proposed canal would pass would be *similar* to that along which the Kendrapara Extension Canal to Jumboo is made. The detail survey of the proposed canal is, I consider, a sufficient refutation of this assumption. I have had the advantage of seeing both the localities, and have had much experience of the soil met with in the Jumboo extension, and have *no hesitation* in stating that if the canal for which I have prepared this scheme passed through a country *similar* to that of the Jumboo Extension Canal, I would hesitate long before I would undertake the construction of the canal, with *even higher* rates than that proposed by Mr. Walker. There is no analogy *whatsoever* between the conditions of the country through which the two canals in question are taken. One is extensively cultivated with regular rows of villages extending for *miles* along the side of the canal line, whilst the other is an uninterrupted tract of low jungle and waste land. The soil at Jumboo is *quite soft,* and is one of the worst descriptions met with on the coast; and in all the numerous tidal works executed under my supervision in Hidgellee, it was found only in one place, on the sea dyke, whereas the soil on the proposed canal is so stiff and impervious to leakage, that we are able to sink pits 10 to 15 feet in depth with almost vertical sides, and with no leakage of water to speak of.

96. In determining on the rates as fixed by me in the accompanying estimate, I have assumed that the work will be executed through the agency of what are generally known as "petty contractors" I see no reason why the work should be otherwise executed, when we can easily get the requisite number of petty contractors, who will complete the proposed works in as *efficient* a manner and as *expeditiously* as any large contractor. As far as we have had experience of works executed by large contractors, there is little or no saving in the cost of the supervising establishment, whether the work be carried out by a single large contractor or by means of a few more petty contractors. In case Government decide in giving out the work to a single contractor, the rates of work will have to be considerably increased over those provided for in the accompanying estimates.

97. In the accompanying Statement I, the nature of the soil as ascertained from actual boring at the sites of the proposed principal masonry works, also in a few places along the line of the canal, has been shewn. The information given in the statement speaks for itself, and it is not necessary for me to reiterate it here, save only to state that, judging from the experience I have had of works on the coast, on *both sides* of the Bay of Bengal, from *Chittagong* down to *Orissa,* I do not think we are likely to meet better soil anywhere on the coast than in what the proposed canals will have to be made. I have not seen ghooting limestone anywhere in the bed of the creeks, save on the coast between the Russulpore to the Dhamra, and along which our line of canal is to be made. In fact, for most of the proposed locks, ghooting will be procured from the beds of the tidal creeks, and that again below the lock sites. *This fact alone,* even without the information given in Statement I alluded to above, ought to be a sufficient proof of the stiff nature of the soil likely to be met with in the excavation of the canal. It is not either the sandy nature of the soil or its compressibility that we

will have to contend against in excavating the proposed canal channel, but its hardness. As regards the supposed leakage from the sides of the canal channel, due to the overflow of tidal waters, the very fact of our being able to sink pits 15 to 10 feet deep without meeting with water ought to be a sufficient refutation of any trouble being apprehended from this source; the soil is too impervious to allow of the leakage. Moreover, the great rise and fall of the tide is a great help for the drainage of the water, both over as well as under the surface of the soil, especially with a flat reach of country on both sides of the canal. Leakage might have given us much trouble if the canal had been made either right at the foot of a slope of country or on its side, but such is not the case in the proposed canals.

98. Much stress has been laid by the opponent of projected canals on the danger of the line crossing so much drainage. This, it is said, will cause so much damage to the canal as to be an insuperable difficulty in maintaining the work in an efficient state. The intercepted drainage waters will, it is said, not only wash the canal banks back into its channel, but also lead to large deposits of silt over its bed, owing to the inundation waters being permitted to enter into the canal and flow over it. It is, I consider, necessary for me to state a few words here in refutation of the above suppositions. First, with reference to the damage likely to be caused to the canal banks by the intercepted drainage waters. Now, this can only happen in case where the canal side banks are *low*, and *weak* and *really* offer any *obstruction* or interfere with the flow of the intercepted drainage waters across it. In Range No. III and portion of Range IVA, up to the 9th mile, there is only the local drainage crossed by the canal, and this has been amply provided for by means of the proposed inlet and outlet sluices. The remaining portion of Ranges IVA and IVB, and portion of Range V, are across the line of inundation waters of the different rivers and of other streams crossed by it. Now, unless the detailed surveys of the sand hills of the sea coast, and of its intersection by the rivers in question, as given in Sheets Nos. 19 to 25 of Book I of the accompanying drawing belie the actual conformation of the coast line, or the calculation of the waterway made by me, as stated in the preceding paragraphs, be incorrect, the line of the proposed canal as now designed, and provided with the numerous flood escapes, *cannot possibly* be stated to *obstruct* in any way the free passage of the inundation waters across it. Reference is solicited both to the detailed plans of the coast alluded to above as well as to the index map of Ranges Nos. IV and V. From the above-mentioned drawings it will be seen how much contracted are the channels of the different streams at their intersection by the sand ridge on the coast. Then, again, the numerous and large villages between the line of the sand ridges on the coast and that of the proposed canal Range No. IVA, from the 9th to the 17th mile, must already in some measure obstruct the flow across of the inundation waters to the coast. The line of the proposed canal with its extensive flood escapes cannot possibly be said to offer any greater hindrance to the inundation water than the villages mentioned above. Some of these villages, such as Bullong, Sartha, &c., are over 1¼ miles in length, and are situated on ridges well elevated above the highest flood level. Then, again, in Range No. V, it will be seen that from the 3rd to the 28th mile there is a regular continuous ridge, covered with villages, to the west of the canal line. This ridge has only four gaps in it for the discharge of the drainage waters of the uplands to the west of it, and where the canal crosses these gaps, due provision of waterway has been made in the proposed flood escapes and sluices.

99. Then it may be asserted that during inundations, with the waters standing to depth of five or six feet above surface of country, the wash of the waves will cause erosion of the side banks. The soil is too *stiff* to allow of much damage from this source, and, moreover, the earthwork estimates provide for the *turfing* of the sides of the spoil banks on both sides, especially in the portions of the canals exposed to the action of the inundation waters. That the inundation waters will not cause much, if any, damage to the side banks of the proposed canal is proved from the existence of the numerous tanks along the line of the canal in the inundated portion. The banks of these tanks are nearly intact, and were besides *never turfed* or *dressed*, and some of the tanks have been in existence some 50 or 60 years.

100. I now come to the important question of silt deposit over the canal bed. The fears on this head are, I beg to submit, greatly *over-estimated*. With regard to the deposit of silt from the local drainage waters, there can be no doubt whatever as to the waters which flow off a cultivated tract of low, flat country with literally little or no fall being free from *silt*. Any one who has gone over the paddy-fields in the low lands on the coast during the monsoons will affirm this. In fact there cannot possibly be any silt in the local drainage waters when we come to consider the fact that the country has no fall, and that the rain waters are simply first accumulated over the country, and then gradually discharged by the tidal creeks, or by the sluices in the protective embankments.

101. The inundation waters which will cross the line of canal hold no doubt a certain amount of silt in suspension ; but, then, the quantity is *so small* as to hardly cause any deposit which will be appreciated or likely to cause any obstruction to the navigation through the canal. If we consider the peculiar formation of the country liable to be submerged by the inundation waters, and the fact that the inundation waters stand over the country for *days* before being finally passed off into the sea, owing to the insufficiency of the channels of the stream and river which intersect the line of the sand ridge on the sea coast, it will be at once apparent that we could not possibly have any tract of country *more favourably* situated for the deposit of silt from the inundation waters than the tract between Nunglessur and the Metai River, or from the ninth mile of Range No. IVA to the end of Range No. V. Yet, if we compare the level of this portion of the coast country with that from the banks of the Bagda river, or the commencement of Range No. III to Nunglessur at the ninth mile of Range No. IVA., and which is not liable to be submerged by the inundation waters, we will find little or no difference between the two. This *incontestibly* proves my assertion that the inundation waters contain little or no silt.

102. To put the matter beyond doubt, we have had specimens of the ordinary inundation water crossed by the line of canal from Nunglessur to the Metai taken at several different localities along the line during the last monsoons, and in none could we detect any sign of silt in any appreciable quantity. These specimens of the drainage waters can, if necessary, be sent up for inspection. Considering the stiff nature of the soil of the drainage basins of the streams crossed by the proposed canals, especially in the case of Range No. V, and that it is nearly all cultivated country, there cannot possibly be much of any silt in the drainage waters by the time they cross the line of canal. The Cuttack Trunk Road, which runs above and parallel to the line of the proposed canals, acts, moreover, as a kind of silt trap, as it checks the velocity of the inundation waters and causes the silt brought from the lands to the west of it to be deposited above it, before the waters are passed across it by the bridges and culverts. As a further proof that the ordinary inundation waters contain little or no silt, we have the fact of the existence of the numerous tanks in the line of the canal exposed to the inundation waters. Now, these tanks have been submerged by the inflow of the inundation water for years, and have not silted up much. The only time that the inundation waters will be likely to hold any silt will be on the occurrence of a heavy rain storm just after the fields have been ploughed for the sowing of the paddy-crops. This is a contingency which very seldom happens, scarcely once in 20 or 30 years. Even if it does occur, the greater quantity of silt in the drainage waters will have been deposited before it reaches the line of proposed canal, if we consider the large extent of almost flat country above it, and which will naturally tend to check the velocity of the drainage waters, and cause the consequent deposit of the silt held in suspension in it.

103. In Ranges Nos. IVA and IVB, the greatest deposit likely to occur will be during extraordinary inundation, when the flood-waters of the Suburnrekha River and Burrabullong spill over their banks. These extraordinary floods happen only once in 10 or 12 years. But, again, it is to be remembered that before the Suburnrekha or Burrabullong flood water spill over the bank, the low tract between Nunglessur and Burrabullong, from the ninth mile of Range No. IVA to the end of No. IVB, will be previously inundated to the extent of 4 to 5 feet above country-level, as explained in paragraph 46 preceding. When, therefore, the flood-waters of the above rivers spill over the bank, the first effect will be to push forward as it were the local inundation waters already standing over the low country ; so that by the time the actual inundation of these rivers cross the canal, the greater part, if not all, the silt contained in it will have been previously deposited. This is further proved, if we consider the general fall of the country, from the river banks towards the low tract along which the canal is taken, as shown by the levels on the index map of Range No. IV. The country on the river bank being high, is a sure indication of the deposit of silt by the flood waters soon after they spill over the banks.

104. To prove beyond any further controversy the fact that the flood waters by merely now and then entering the canal deposit no silt over its bed, I have had sections taken of the Ranges No. II and III of the Orissa High Level Canal. These two sections of the High Level Canal were inundated by the flood waters of the Byturnee River in July 1877, when the floods breached both the protective embankments, the trunk road and canal side bank, and got into the above two ranges. The cross sections alluded to above are given in Sheet No. 26 of Book I of the accompanying drawing. On comparing the levels of the bed as it now exists with its normal level to which it was originally excavated, it will be seen that very little or no silt has been deposited, and the little that has been deposited is probably due to the washing in of the

side banks before the canal was filled up with water. In a newly-excavated canal there is always more or less a slight deposit of silt due to this cause. Now, the country above these two ranges of canal has generally a fall of 8 or 10 feet per mile, and further it is to be remembered that the flood waters of the Byturnee at the crossing of the High Level Canal will naturally contain a much larger proportion of silt than any inundation which is liable to cross the line of the projected coast canal. Yet, in spite of the disadvantages noted above, there seems from these cross sections of the canal alluded to above to be little or no deposit of silt, due to the entry into the canals in question of the inundation water of the Byturnee river in July 1877.

105. From the facts stated in the preceding paragraphs, I trust I have sufficiently proved that the fears entertained of the projected canal being damaged or silted up by the inundation waters being allowed to cross it are greatly exaggerated. Looking merely at the general map of the line of the canal, it appears no doubt to be a *formidable* undertaking to propose the construction of line of canal across so much drainage; but if the project be examined *impartially*, and the *conditions* under which the drainage likely to be intercepted by the canal is *at present discharged*, it will be found that the difficulties to be overcome are not, after all, so great or insuperable either as regards the construction of the works or its future maintenance. The proposed mode of passing the intercepted drainage and inundation waters over the canal by means of the flood escapes is not so novel a work as apparent at first sight. It is simply a modification of the causeway already used successfully in the Cuttack Trunk Road and elsewhere. It is *satisfactorily* proved that the inundation waters which cross the canal do not carry silt in any appreciable quantity. Then, there can be no doubt whasotever but that the proposed flood escapes are the *best*, the *most economical*, and the *safest* means of providing for the passage of the intercepted drainage and inundation waters across the line of the projected canals.

106. As regards the deposit of silt from the inundation waters, I trust the measures already proposed, *viz.*, that of lowering the canal bed-level in front of the escapes and sluices and also of the bed of the channels on the up stream of these works, will be considered sufficient. In addition to this, in order to provide against any possible deposit from the extraordinary inundation waters of the Suburnrekha and Burrabullong rivers, I have lowered by one foot the bed-levels of Ranges Nos. IVA and IVB; in other words, the minimum depth of water in these two ranges is to be *eight* feet instead of the usual *seven* feet allowed for Ranges Nos. III and V.

107. As regards damage from cyclone-waves, the whole of Range No. III and northern half of Range No. IVA, or up to the ninth mile of Nunglessur, is entirely protected against it, as will be seen in referring to the index maps. In the remaining portions of the canals the continuous line of ridge of sand hills on the sea coast will afford sufficient protection. The only way by which the storm-wave could enter will be through the gaps in the ridge, due to its intersection by the different sections which discharge through it the inundation water into the sea. The area of these gaps, as will be seen from the surveys and section given in sheets Nos. 19 to 25, Book I, of the accompanying drawing, is not much, if compared with the area of the low country likely to be inundated by the storm-wave. Moreover, whenever a cyclone happens, there is generally heavy rainfall, which causes the local inundation waters to stand to a depth of 5 to 6 feet above country level. The only effect of the cyclone-waves entering through the gaps in the sand ridge on the coast will be to raise by a couple of feet or so the level of the local inundation waters, and I have previously, in paragraphs preceding, shown that there is sufficient waterway provided across the canal for the passage of the highest flood waters.

108. It is a *singular fact* that none of the numerous opponents of this scheme has been able as yet to discover the really *weak point* of the projected canals, and which is its liability to have silt deposited over its bed, from the unavoidable entry of the tidal waters required to feed it, during the dry season. The prevention of the deposit of silt from the tidal waters is in fact the real *great difficulty* we have to contend against in the projected canals. If we could continue to feed the canal with waters as free from silt as the monsoon drainage waters, the maintenance charges of the canal would be reduced to the lowest possible amount. It is the deposit of silt brought in by the tidal waters entering the low-level canal which chiefly enhances the cost of the annual repairs of such canals. I trust, however, the measures proposed by me to prevent the entry of silt with the tidal waters during the dry season, as explained in paragraph 64 preceding, will be considered sufficient. In addition to the proposed supply sluices, I have made the heads of the projected canals for two miles next to the

terminal locks two to three feet lower than the normal level determined for each range, as will be seen on referring to the longitudinal sections of the different ranges. These lowered portions of the beds next to the locks will act as silt-traps as it were for the silt brought in by the tidal waters which will necessarily enter into the canal through the lock when it is worked for the passage of the boat, or by leaking in through the gates and between the gates, and the sills and the hollow quoins. I have therefore taken every *possible precaution* to reduce to the *lowest possible* limit the deposit of silt due to the unavoidable entry of the tidal waters into the canal, either in the dry season or during the monsoons.

109. TOTAL COST OF THE PROPOSED CANALS.—In Statement J and J^1, I have shewn the total cost of work, or of the direct charges for the canal with the minimum bottom width of 40 and 50 feet respectively. The difference between the two amounts to R 1,56,139, which is accounted for as follows, *viz.*—

	R
Land	3,500
Earthwork	1,17,489
Establishment	30,259
Tools and plant	4,841
Total	1,56,139

From the above total, the excess charge for establishment and tools and plant should be deducted, as no additional supervision or tools and plant will be required for giving a 50-feet minimum bottom width to the canal instead of 40 feet. The actual total excess quantity of earthwork to be executed for a 50-feet minimum bottom width of canal is 311 lakhs of cubic feet, and that scattered over 92 miles of canal. The total quantity of earthwork for a canal with a minimum bottom width of 40 feet is 3,200 lakhs of cubic feet. It is therefore obvious that if, in addition to this, we have to execute another 311 lakhs of cubic feet, required to increase the minimum bottom width to 50 feet, we cannot possibly require any larger establishment, especially as it will be scattered over a length of 92 miles of canal, and is besides not likely to delay the completion of the work. The difference in the quantity of earthwork between a Canal of 40 feet and a 50-feet bottom width is comparatively speaking so small, as regards the total quantity required for the canal, as not to affect the period of its completion. As it is not intended to supply to the contractors any tools for excavation of the canal, the additional amount provided for it, for the 50-feet bottom width canal, seems to be also unnecessary. If the additional charges for establishment and tools and plant be deducted as proposed above, the total direct charges for the canal, with a minimum bottom width of 50 feet, will be R35,92,392, or R1,21,034 more than that for the canal of 40 feet bottom width. I have, however, in the Statement J^1 allowed for the full percentage charges for establishment and tools and plant. The proposed deduction can be afterwards made if considered necessary.

110. The establishment charges have been assumed at 25 per cent. on the cost of the works, though I am still of opinion that if only the staff of assistants and subordinates actually required for the works were placed on it, the cost of the establishment will not exceed 20 per cent., as originally estimated by me. In determining the probable cost of establishment required for a new work, we ought to take into consideration the *rates* of *masonry works*, and the *proportion* of *earthwork* as compared with the other items of the estimate. Now, in the proposed canals, the amount of the estimate for the excavation of the channel of the canal comes up to 50 per cent. of the total amount of the estimates for all works; but if we take into consideration the large quantities of earthwork to be done in connection with the masonry works, as provided for in the estimates for these works, the actual percentage of earthwork will be about 60 per cent. of the total amount of the estimate for all works of the canal. Then, again, from the masonry estimates it will be seen that the rates of masonry are very high, ranging from R25 to over R30 per 100 cubic feet. For the reasons stated above, it will be seen that the cost of establishment for the projected work should not be much, as the earthwork requires less skilled supervision, and therefore does not generally cost much for establishment. As far as masonry works are concerned, it is obvious that the higher the rates the less will be the percentage of cost of establishment required for its supervision. I have, however, in the

estimate provided the full percentage of 25 per cent. on the cost of the works for the establishment charges, as in these days of superfluous engineers and subordinates it is most likely that employment will have to be found for a greater number of officers and subordinates on the works of the proposed canals than what will be actually required for the sake of the work itself.

111. For tools and plant I have allowed 4 per cent. on the cost of the works. The tools and plant will be required chiefly for the masonry works. I will compare this percentage with that on the Hidgellee Tidal Canal. The total expenditure shown against these canals, under the items of tools and plant, is R57,585; but from this is to be deducted R31,775 on account of general agency and transport charges of the general project of late East India Irrigation and Canal Company, as has been ascertained on reference to the Examiner. When the works were transferred to Government in 1869, the amount charged against tools and plant to the tidal canal account was R41,367, whilst value of the tools actually made over come up to only R9,694 according to a valuation statement prepared by the late Company's *own* officer; the balance the Examiner, in his No. 7389 of 26th September last, states was for general agency and other charges as explained above. So that difference between R41,367 and R9,694, or R31,773, is to be deducted from R57,585, or the total amount alternately charged against the tidal canals on account of tools and plant, and which ought therefore to be R57,585—31,775, or R25,810: this is inclusive of cost of the ferry-boats, &c. The total cost of works of the tidal canal in Hidgellee is R12,66,239—187,195, or R10,89,044, leaving out the charges under the head of English expenditure, on account of Directors' fees and other home office charges of the late East India Irrigation and Canal Company. Taking the above amount, R10,89,044, as the actual expenditure on works, the proportion of the tools and plant charge on the cost of works is about 2·4 per cent., and I have allowed 4 per cent. in the estimates for the projected canals. In the construction of these canals the only charges on account of tools and plant is chiefly that for the purchase of engines for the pumping of water, whenever necessary, from the foundation pit of the locks, and for the grinding of mortar for masonry. As we will get some second-hand engines transferred at a valuation from other works, the cost of this will be much reduced. Then, again, some allowance ought to be made for the value of the engines, &c., after the completion of the work. Even exclusive of this, the tools and plant on the tidal canal cost only 2·4 per cent. on the cost of the works. The 4 per cent. allowed by me will be more than ample for all tools and plant and ferry-boats, as well as small steam scrapers and dredgers, required for the proposed canals. I do not see any necessity of assuming a higher percentage and unnecessarily increasing the total cost of the proposed works.

112. In statements marked K and K,[1] the totals of direct and indirect charges have been given for a canal with a minimum bottom width of both 40 feet as well as 50 feet. The rate of interest has been assumed at 7 per cent. on the whole of the direct charges; this is on the supposition that the projected works will be all completed within three years. I see no reason why we should not be able to do this, considering so much of the work consists of earthwork, for which the required labour is abundant, and that the principal masonry are only the eight terminal locks. In asserting that the proposed works will be finished within three years, I only state what I think I will be able to do from the progress of similar works under my charge. It is, moreover, quite probable that at least one range of the proposed canals, *viz.*, Range No. III, between the Bagda and Suburnrekha River, will be completed in two years, and paying some revenue in the third year. Then it may be asserted that, even suppose the work were completed in three years, there would not be the full extent of traffic in the first year or two. This will of course appear as probable to those who do not know the resources of the district. But any one acquainted with the resources of the district in the neighbourhood of Calcutta, as regards the supply of boats, &c., would have no hesitation in stating that as soon as the canal was open there would be no want of traffic on it, nor would the traffic be likely to be hindered from any want of boats, as, in addition to the supply of boats from the Calcutta end of the canal, there would be boats from Orissa, and even many of the sloops in Balasore could be used on the canal, as there will be sufficient depth of water for such vessels, and the locks on the canal are of sufficient width to allow of the passage of such vessels. The natives are quite alive to the benefits of inland water communication, and there is no doubt they will take advantage of it as soon as they have an opportunity to do so. A single visit to Balieaghye at any period of the year will be sufficient to convince the greatest sceptic on this point, and show him how incessant the traffic there is, and how the natives seem to appreciate the

advantages of water communication. I do not think there need be any fear as to the want of boats for the traffic on the canals when once opened; at least there will anyhow be boats sufficient for the estimated traffic along the projected canals.

113. From the statements K and K,^{1} it will be seen that the amount of both the direct as well as the indirect charges will be R38,71,895, or R40,45,016, according as the minimum bottom width of the proposed canal is made 40 feet or 50 feet. If the deduction proposed in paragraph 109 preceding, on account of the establishment and tools and plant charges, be made for the estimates for 50-feet bottom width canal, the total amount of the estimates of both direct and indirect charges will be reduced to R40,01,407, or (say) in round numbers R40,00,000. This is R7,00,000 in excess of the approximate estimate made by the Chief Engineer in his note of the 15th February 1877. This excess is chiefly due to the following causes :—

1st.—The length of canal is increased from 91 miles to 93 miles. This increase is due to the re-alignment of the first 12 miles of the northern terminus of Range No. III, and of the last mile of the southern terminus of Range No. V, and was *absolutely* necessary.

2nd.—The mean bottom width of the canal is increased from 40 to 55 feet nearly.

3rd.—Preventive works required to keep out the tidal silt from the canals.

4th.—Two additional locks provided, *viz.*, those for Range No. IVB.

5th.—Establishment and tools and plant charges increased from 20 and 3 per cent. to 25 and 4 per cent., respectively, on the total cost of works.

6th.—Interest charges increased from 6·75 to 7·00 per cent.

114. The mean bottom width of the canal was originally fixed at 40 feet, but on preparing the detailed estimates it was found that the bottom width would in several places have to be increased, to provide earth for raising the side banks of canal above flood level. In addition to this, the bottom width of the canal for two miles next to the terminal locks was increased to an average of 55 feet. On account of the above alteration the mean bottom width of the canal becomes 48 feet or 55 feet, according as we make the minimum bottom width 40 or 50 feet. As regards the preventive works against the entry of silt with the tidal waters, there can be no doubt as to the *expediency* and *utility* of the proposed work in diminishing the ultimate maintenance charges of the canals. From paragraph 11 of Chief Engineer's note of 15th February last, it will be seen that it was not then proposed to lock Range No. IVB between the Panchpara and Burrabullong rivers. This was afterwards, from the inconvenience to navigation experienced in the portion of the Midnapore Canal between the Damooda and the Roopnarain rivers, found to be *indispensably* necessary, and was provided for accordingly. The necessary explanation as regards the increase of the percentages for establishment, tools and plant and interest charges, have been given in paragraphs 110 and 111 preceding, and need not be reiterated here.

115. In statements marked L and L,^{1} M and M,^{1} the mileage rate of cost of the direct and indirect charges both for a 40-feet as well as for a 50-feet bottom width canal have been given. The total cost of the canal, with the 40-feet channel, comes to R37,426·98, or (say) R37,500 per mile, and for a 50-feet channel to R39,000 per mile. This is certainly not *excessive* for a first-class navigable canal, with an average depth of 10 feet, and average mean width of 75 feet at level of water-surface for a 40-feet channel, or 85 feet for a 50-feet channel. For works alone the cost per mile is R29,000 or R30,300, according as we provide for a channel of a minimum bottom width of 40 or 50 feet. In Madras the coast canal cost on an average about R22,000 per mile for works alone, and that without any locks or sluices, &c., or other masonry works. The channel provided for this has a mean depth of 5 feet and mean surface width 55 feet, the bottom width of the canal being 30 feet and the minimum depth only 3 feet. This is far less than that of the canal proposed here, and which will have a minimum bottom width of 50 feet, and a depth of 7 feet, or nearly *more than double* that of Madras coast canals. There can, therefore, be no doubt as to the comparative cost or the advantages for navigation purposes of the two lines; and from what I have seen of the Madras canals, I have no hesitation in stating that it has not half the advantages for uninterrupted navigation as the proposed canals here will have, and in addition to this the cost of the maintenance of the former will be much more than that of the latter, owing to the sandy nature of the soil on the coast at Madras.

116. I have only to discuss the merits of the scheme in a financial point of view, and in doing this I will assume that Government will, if it sanctions the work at all, approve of the

canal with a minimum bottom width of 50 feet at a cost of R40,45,016, or (say) in round numbers 40½ lakhs of rupees. Taking the rate of interest at 4½ per cent., and the maintenance cost at Rs. 800 per mile, as determined by the Chief Engineer in his note of the 15th February last, the amount required annually to meet the above charges will be as follows, *viz.*—

	R
Interest on 40½ lakhs of rupees, at 4½ per cent. per annum	1,82,250
Maintenance for 93 miles, at R 800 per mile	74,400
Total .	2,56,650

To meet this expenditure of R2,56,650 annually, the least amount of revenue likely to be realized from the projected canals will be R2,60,000,—*vide* paragraph 57 of the Chief Engineer's note of the 15th February last. The cost of the maintenance of the projected canal will be considerably reduced if, as I confidently anticipate, the proposed method of feeding the canal during the dry season through the supply sluices answers. However, to be on the safe side, I have in the above calculations assumed the full amount per mile fixed by the Chief Engineer in his note of the 15th February last. In the amount of probable revenue from the canals, we have not taken into account the probable increase in the traffic from the Gurjats or hill tracts of Orissa. Considering the extensive tracts of various descriptions, first-class timber forest in the Gurjats, and the growing demand for good timber in Bengal due to the extension of railways, there can be no doubt but that as soon as the projected canal affords the required facilities for transport of timber to Calcutta, large quantities of it will be exported from Orissa to the Presidency. Even now, with all the drawback of 60 miles of land carriage, large quantities of sâl logs are sent to Baliaghye from Balasore, and they have also begun to bring timber down the Suburnrekha River as far as Dantoon, whence it is carted to the Midnapore Canal and sent on to Calcutta. I fully expect that, when the canals are opened out, the demand for timber from Orissa will be so great as to necessitate Government to make some arrangements with the Gurjat rajahs to prevent the reckless destruction of the forest which is sure then to be cut down indiscriminately if no steps are taken to properly conserve it. This Government will probably have to do for its own sake to get for its State railways the sleepers required for it. In addition to the timber from the Gurjats, there is sure to be other produce, such as oil-seeds, gum, and drugs, &c. The following extract from the Government Resolution of the Revenue Department of the 26th November last will show to what extent the trade of Orissa has increased since 1873-74:—

"THE ORISSA PORTS.

"*Paragraph 43.*—The foreign trade of the Balasore ports is of slight importance. During the past year there were no imports, and the value of the whole trade declined from R1,97,558 to R1,66,235. The customs duty rose from R18,224 to 28,138; but the export duty shows a decrease of nearly R6,000 in consequence of a great portion of the export of rice having been diverted to Madras instead of going to Ceylon, Mauritius, and the Maldives.

"*Paragraph 44.*—The following statement illustrates the remarkable growth of the coasting trade of the Balasore ports during the last five years:—

	1873-74.	1874-75.	1875-76.	1876-77.	1877-78.
IMPORTS.					
Merchandize.	R	R	R	R	R
Indian produce	18,969	7,594	6,57,853	7,29.189	12,13,386
Foreign merchandize	4	......	11,25,499	14,58,735	22,22,741
TOTAL . .	18,973	7,594	17,83,352	21,87,924	34,36,127
Treasure	27,850	3,450	2,83,350	12,39,553	19,00,062
TOTAL . .	46,823	11,044	20,66,702	34,27,477	53,36,189
EXPORTS.					
Merchandize.					
Indian produce	2,19,492	2,47,636	13,66,669	29,61,655	49,08,643
Foreign merchandize	......	......	9,139	5,696	1,786
TOTAL . .	2,19,492	2,47,636	13,75,808	29,67,351	49,10,429
Treasure	10,000	......	2,52,057	8,55,823	7,86,937
TOTAL . .	2,29,492	2,47,636	16,27,865	38,23,174	56,97,366
TOTAL TRADE . .	*2,76,315	*2,58,680	36,94,567	72,50,651	1,10,33,555

* The figures for trade with other ports in the Presidency are not included.

"Excluding treasure, the imports show an increase of nearly 12½ lakhs, and the exports of nearly 19⅓. Cotton twist and piece-goods, copper, betel-nuts and apparel were imported in large quantities to meet the demand created by the money which had been poured into the country in payment for agricultural produce. At one time towards the close of the past year the stock available in the district had been reduced so low that several cargoes of rice were imported into Chandbali by steamer from Calcutta, in order to complete the cargoes of ships which had been chartered at the former port, but which could not obtain enough rice at Chandbali. The enhanced exports were mainly due to extensive shipments of rice to Madras in answer to the famine demand. It is stated that the quantity of rice and paddy exported did not much exceed the exports of the previous years but the price was considerably higher. Further enquiry has shown that the statement made in last year's resolution, that a large proportion of the rice shipped at Chandbali was the produce of the Cuttack District, was scarcely correct. A small quantity of the rice grown in the tract between the Brahminee and Byturnee rivers in Cuttack is sent for shipment to Chandbali, but the bulk of rice exported from Chandbali comes from the southern part of Balasore and the tributary estates. Rice is also sent from Chandbali by inland creeks to False Point for shipment. The export of hides shows an improvement of three lakhs, and the timber trade of two lakhs. Nearly all of this timber is sâl or sisoo wood from the tributary estates, and it is satisfactory to find that the improvement of communications which has gone on of late years in Orissa has rendered it possible to bring the natural produce of these estates into export market.

"*Paragraph 45.*—The value of the foreign imports of Cuttack in 1877-78 was 2,836. They consisted chiefly of liquors and provisions imported from England for private consumption. During the three years previous there were no foreign imports at all. The foreign exports fell from R5,53,923 to R4,04,192 in consequence of the demand in the coasting trade, which diverted to Madras a large proportion of the rice which, in ordinary years would be sent to Mauritius, Colombo and Jedda.

"*Paragraph 46.*—The coasting trade of Cuttack during the past five years may be shown as follows .—

	1873-74.	1874-75.	1875-76.	1876-77.	1877-78.
IMPORTS.					
Merchandize.	R	R	R	R	R
Indian produce	26,390	16,678	2,96,751	3,16,593	11,04,250
Foreign merchandize	7,000	6,694	10,57,435	7,42,170	18,17,083
TOTAL	33,390	23,372	13,54,186	10,58,763	29,21,333
Treasure	1,05,650	......	24,420	1,29,310	6,79,854
TOTAL	1,39,040*	23,372*	13,78,606	11,88,073	36,01,187
EXPORTS.					
Merchandize.					
Indian produce	2,44,946	3,66,915	2,35,367	13,75,620	30,10,717
Foreign merchandize	115	26	3,128	212	10,943
TOTAL	2,45,061	3,66,941	2,38,495	13,75,832	30,21,660
Treasure	11,000	......	6,65,000	9,76,350	2,50,000
TOTAL	2,56,061*	3,66,941*	9,03,495	23,52,182	32,71,660
TOTAL TRADE	3,95,101*	3,90,313*	22,82,101	35,40,255	68,72,847

* These figures do not include the trade with other parts in Bengal.

The increase in imports last year would seem to show that the trade by sea has taken the place of trade by road, while the exports were stimulated by the requirements of the distressed districts of Madras and Bombay.

"*Paragraph 47.*—The port of Pooree, which is in fact nothing more than an open roadstead, has now foreign import trade, and the value of the export trade to foreign ports fell during the past year from R66,642 to R7,287. The usual export of rice to Ceylon entirely ceased in consequence of activity of the coasting trade, and there was only a small shipment of myrabolams to the United Kingdom. As there were no exports of dutiable products, no customs revenue was realized during the year. In the coasting trade the imports of merchandize fell from R29,275 to R25,447, and the imports of treasure from R72,000 to R37,184. During the past year the outturn of rice throughout the district was below the average, and prices rose abnormally high. The exports accordingly declined in value from R6,65,929 to R5,55,609; other causes helped to diminished the exports from Pooree itself. The canal leading to False Point, which is usually closed during the hot season, was open the whole year, and large quantities of grain which otherwise might have been exported to Madras from Pooree were shipped at False Point. At the same time a considerable trade was carried on by land between Pooree and the district of Ganjam in Madras through the Government estate of Khoordah. Salt is imported from Ganjam by bullock-carts which return laden with rice."

117. I have in this report supplied all the information regarding the project in an engineering point of view, and have, I trust, proved satisfactorily the feasibilty of the proposed canals. The financial aspect of the scheme has been discussed fully in my previous report of June 1877, and which was reviewed by the Chief Engineer in his note of the 15th February 1878. There will, I hope, be no further discussion of the extension of the High Level Canal after the advantages of the proposed canals have been so clearly shown in the Chief Engineer's note of 5th October 1877. Even if the High Level Canal could be cheaply made, the disadvantages of crossing the rivers above the anicut during the monsoons, and of four miles of dangerous river navigation, between Ranges Nos. I and II, would always make navigation by this route very unsafe and precarious during the rains. Then, again, there is no water available for the supply of the extension between Bhuddruck and Balasore. When I prepared the estimate for this extension, I calculated on obtaining the requisite supply of water only for navigation purposes for this line from the Brahminee and Byturnee; but now, according to the statement made in paragraph 8 of Mr. Walker's letter No. 3118, of the 8th December 1877, we cannot expect to get even 175 cubic feet per second from these rivers after the wants of Ranges Nos. II and III have been met. Even if we could get about 200 cubic feet for thi sextension, it would suffice for leakage, lockage and evaporation only, and the canal would practically be simply a still-water channel. Considering the extensive and rapid growth of weeds in the freshwater canals in Orissa, with even a continuous current through the channel, it can be better imagined than described how *expensive* and *inconvenient* it will be to keep free from weeds a level reach of 55 miles of canal, with a channel of at least 50 feet bottom width. In the proposed coast canal we will be entirely free from weeds, and this of itself is a great point in its favour, and against the High Level Canal extension. Moreover, if Government decide in providing irrigation for the tract between Balasore and Bhuddruck, the extension of High Level Canal, even if it were made, would be of no use, unless we construct extensive reservoirs up the basin of the Salundi River, and stored up the required supply of water. But if reservoirs are to be made, it would be much better and cheaper for obvious reasons to make a number of small reservoirs in the range of hills which run parallel to the trunk road between Balasore and Bhuddruck, and to construct thence a number of small canals for irrigation purposes. These canals would be *parallel* to the drainage, and would, moreover, provide irrigation for *more* than *twice* the area supposed to be provided for by the proposed extension of the High Level Canal which is to run close to the trunk road, and leave unprovided with irrigation the high lands between the range of hills mentioned above and the road, and which has *greater* need of irrigation than the tract between the road and the sea coast.

118. In conclusion, I have only to state that the Government has now before it all the information necessary for its decision as to the future of this scheme, whether it is to be proceeded with at once, or indefinitely postponed. Though it is not for me to assert it, yet I would respectfully beg to submit that there has been seldom laid before Government a scheme with such *full* and *accurate* information as to its *success* in a *remunerative* point of view. I do not think any such information as that which was collected regarding the probable amount of traffic on the proposed canals was ever before required or submitted for any line of navigable canal, or a railway, whether State or Guaranteed. It is further to be remembered that the trade report of this canal, after being subject to the criticism of the local Revenue authorities, was found to have estimated the amount of probable traffic, if anything, *less* than what it would most probably be. As regards the engineering details, it is hoped that the information given in this report and the accompanying plans and estimates will be sufficient for Government to finally decide on the feasibility of the scheme.

J. C. VERTANNES,
Executive Engineer, Balasore Survey Division.

BALASORE,
The 10th January 1879.

APPENDIX A.

List of works and land for the proposed Orissa Coast Canal, Ranges Nos. III, IV, and V.

Distance from head in miles and feet.		Names of Works.	Average width of land taken up.	Width of bottom of channel.			Slope of bed.	Depth of water.		Supply sluices.		Inlet sluices.		Outlet sluices.		Flood escape, lineal feet.	Inspecting Bungalow.		Terminal lock.	Height of tow-path above bed.	Minimum height of side bank above highest flood level.	Remarks.
				Minimum.	Mean.	Maximum.		Minimum.	Maximum.	Number.	Spur.	Number.	Spur.	Number.	Spur.		Permanent.	Temporary.				
Miles.	Ft.	*Range No. III.*	Ft.	Ft.	Ft.	Ft.		Ft.	Ft.		Ft.		Ft.		Ft.							
...	250	Main canal	200	50·00	56·00	86·50	Level.	7·00	11·00	20	5	...	...	...	...	......	...	2	1	12·50	3·00	Opposite Surpai.
8	3,880	Ditto								...	...	3	5	...	...	......	...	1	...			At Jharasurra.
11	4,200	Ditto								...	...	6	5	...	...	......	...	...	...			At Bissonathpore.
12	800	Ditto								...	...	...	...	8	5	......	...	...	...			At Doodha.
12	1,200	Ditto								...	...	12	5	...	...	......	...	...	...			Ditto
30	400	Ditto								...	...	2	5	...	...	......	...	...	...			At Burtua.
30	1,000	Ditto								3	4	...	...	...	...	......	...	...	...			Existing sluice on the Government embankment to be remodelled.
30	1,000	Ditto								...	...	2	4	...	...	......	...	...	...			Inside bank of Burtua supply channel.
30	5,080	Ditto								...	...	1	5	..	...	......	...	...	...			At Bhograi.
31	1,320	Ditto								...	...	...	...	...	...	......	...	1	1			Ditto
		Range No. IVA.																				
...	250	Main canal	250	46·00*	56·00	74·00	Level.	8	12·50	...	...	...	...	...	...	......	...	2	1	17·50	3·00	At Jamcoonda.
...	4,750	Ditto								...	...	2	5	...	...	......	...	...	...			In Soolsa Pat.
8	600	Ditto								...	...	2	5	...	...	......	...	...	...			Ditto
9	3,000	Ditto								...	...	...	...	...	..	600	...	...	...			At Gonga.
9	4,800	Ditto								...	...	2	5	...	...	......	...	...	...			At Boolung.
10	4,300	Ditto								...	...	3	5	...	...	......	...	...	...			Ditto.
11	2,250	Ditto								...	...	...	...	3	5	......	...	...	...			Ditto.
11	3,250	Ditto								...	...	...	...	...	...	1,000	...	...	...			At Judpore.
12	3,600	Ditto								...	...	...	...	...	...	1,000	...	...	...			At Koonde.
13	3,550	Ditto								...	...	...	...	...	...	1,000	...	...	...			Near Sartha Khall.
14	......	Ditto								...	...	...	...	5	5	......	...	...	...			Ditto ditto
14	600	Ditto								...	...	5	5	...	...	......	...	...	...			Ditto ditto
14	2,100	Ditto								..	...	...	...	...	...	1,000	...	...	...			At Sartha.
15	3,000	Ditto								...	...	...	...	...	...	1,200	..	...	...			At Orissa.
16	2,450	Ditto								...	...	...	...	..	...	1,000	...	1	1			At Panchpara.
17	250	Ditto								10	5	...	...	...	...	......	...	1	1			Ditto

		Range No. IVB.																				
...	250	Main canal	240	46·00*	50·00	60·00	Level	8·00	13·50	10	5	...	...	...	...	......	...	1	1	18·50	3·00	At Soolpatta.
1	......	Ditto								...	...	...	...	...	...	1,250	...	...	...			At Chaoolpora.
1	1,200	Ditto								...	...	2	5	...	...	......	...	...	...			Ditto.
3	200	Ditto								...	...	3	5	...	...	......	...	...	...			At Gobri Nullah.
3	1,200	Ditto								...	...	...	...	...	...	1,250	...	...	...			At Gorda.
4	2,900	Ditto								...	...	...	...	...	...	1,500	...	...	...			At Koosdea.
5	3,000	Ditto								...	...	2	5	...	...	......	...	...	...			At Bhagrutpore.
6	1,800	Ditto								...	...	...	...	10	5	......	...	...	...			At Nollcoll.
6	2,800	Ditto								...	...	...	...	...	...	......	...	1	1			Ditto.
		Range No. V.																				
...	250	Main canal	220	50·00	51·25	60·00	Level	7·00	10·50	...	...	...	...	...	...	......	...	1	1	15·5	3	At Chargatchea.
1	1,700	Ditto								...	...	3	5	...	...	......	...	...	...			At Sukoona.
1	1,900	Ditto								...	...	...	...	4	5	......	...	...	...			Ditto.
2	4,200	Ditto								...	...	...	...	...	...	400	...	...	...			At Heeregoan.
5	1,500	Ditto								...	...	3	5	...	...	......	...	...	...			At Balidari.
5	1,800	Ditto								...	...	...	...	3	5	......	...	...	...			Ditto.
6	2,100	Ditto								...	...	...	...	...	...	600	...	...	...			At Prag Nullah.
9	4,300	Ditto								...	...	2	5	...	...	......	...	1	...			At Koomarpore.
12	2,800	Ditto								...	...	2	5	...	...	......	...	...	...			At Jamoa Nullah.
12	3,000	Ditto								...	...	...	...	2	5	......	...	...	...			Ditto.
12	5,200	Ditto								...	...	...	...	...	...	1,000	...	...	...			Ditto.
13	3,100	Ditto								...	...	...	...	...	...	1,000	...	...	...			At Talpuda Nullah.
13	4,700	Ditto								...	...	4	5	...	...	......	...	...	...			Ditto.
13	4,900	Ditto								...	...	...	...	4	5	......	...	...	...			Ditto.
14	...	Ditto								...	...	...	...	...	...	......	...	1	...			At Patua Village.
20	2,500	Ditto								...	...	...	...	...	...	......	1	...	...			At Atlabad.
21	...	Ditto								...	...	...	...	...	...	600	...	...	...			At Sylucbpore Nullah.
21	1,200	Ditto								...	...	2	5	...	...	......	...	...	...			Ditto ditto.
21	1,500	Ditto								...	...	...	...	2	5	......	...	...	...			Ditto ditto.
22	900	Ditto								...	...	...	...	...	...	1,400	...	...	...			At Kashbash Nullah.
22	2,700	Ditto								...	...	8	5	...	...	......	...	...	...			Ditto ditto.
22	2,750	Ditto								...	...	...	...	5	5	......	...	...	...			Ditto ditto.
27	1,400	Ditto								...	...	2	5	...	...	......	...	...	...			At Gummaie Nullah.
27	1,500	Ditto								...	...	...	...	2	5	......	...	...	...			Ditto ditto.
27	2,100	Ditto								...	...	...	...	...	...	1,000	...	...	...			Ditto ditto.
30	...	Ditto								...	...	...	...	...	...	......	...	1	...			At Mugrajpore.
31	...	Ditto								...	...	...	...	...	...	1,000	...	...	...			At Bousur.
32	3,100	Ditto								...	...	2	5	...	...	......	...	...	...			At Juggernathpore.
34	5,100	Ditto								...	...	2	5	...	...	......	...	...	...			At Apertipore.
37	4,800	Ditto								...	...	...	...	...	...	......	...	2	1			At Charbatea.
		Head-quarters of the Division.	......	......	......	......	......	......	......	...	...	...	...	...	...	......	1	...	...	......	......	Office and store godown at Balasore.

* With 7 feet minimum depth, the bottom width of this range will also be 49 feet, or say 50 feet nearly, as in the other two ranges.

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APPENDIX B.

General Abstract of cost of works for the proposed Orissa Coast Canal, Ranges III, IVA, IVB, and V.

CLASSIFICATION.	CANAL RANGE				TOTAL.	GRAND TOTAL.
	No. III.	No. IVA.	No. IVB.	No. V.		
	R	R	R	R	R	R
A.—Preliminary expenses	3,000	2,000	1,500	3,500	10,000	
B.—Land	47,605	16,963	8,317	35,021	1,07,906	
D.—Regulators	23,512	10,649	10,649	......	44,810	
F,—River and hill torrent works	29,016	22,774	18,361	56,703	1,26,854	
F(1)—Other cross drainage works	7,121	20,212	. ....	......	27,333	
H.—Escapes	......	13,600	8,000	14,000	35,600	
I.—Navigation works	2,15,422	2,27,264	2,23,398	2,10,662	8,76,746	
K.—Buildings	9,000	6,750	5,500	18,000	39,250	
L.—Earthwork	3,74,336	3,08,096	1,37,318	5,75,749	13,95,499	
Drainage and Protective Works						
L.—Earthwork	......	......	......	7,112	7.112	
Total works	7,09,012	6,28,308	4,13,043	9,20,747	26,71,110	
Establishment at 25 per cent.	......	......	......	......	6,67,778	
Tools and plant at 4 per cent.	......	......	......	......	1,06,854	
Total direct charges	......	......	......	......	......	34,45,742
Indirect Charges.						
Pension allowance at 20 per cent. on establishment	......	......	......	......	1,33,555	
Capitalised abatement of land revenue	......	......	......	......	23,000	
Total indirect charges	......	......	......	......	......	1,56,555
GRAND TOTAL	......	......	......	......	......	36,02,297

J. C. VERTANNES, C.E.,
Executive Engineer, Balasore Survey Division.

APPENDIX C.

Detailed Abstract of cost of works for the proposed Orissa Coast Canal, Ranges III, IVA, IVB, and V.

CLASSIFICATION.	DETAIL OF WORK.	Amount of estimate.	TOTAL.
	Range III.	R	R
A.—Preliminary	Preliminary expenses	3,000	3,000
B.—Land	Cost of land	47,605	47,605
D.—Regulators	2 Supply sluices of 10 vents of 5 feet each	21,298	
	Remodelling existing sluices of 3 vents of 4 feet each	2,214	23,512
F.—River and hill torrent works.	Inlet sluice of 3 vents of 5 feet each	2,624	
	Ditto of 6 do. of 5 ditto	4,760	
	Ditto of 12 do. of 5 ditto	8,762	
	Ditto of 2 do. of 5 ditto	1,942	......
	Carried over		......

APPENDIX C.—(*continued.*)

CLASSIFICATION.	DETAIL OF WORK.	Amount of estimate.	TOTAL.
	Range III—contd.	R	R
	Brought forward .	...	...
F.—River and hill torrent works—(*continued*).	Inlet sluice of 2 vents of 4 feet each	861	
	Ditto of 1 do. of 4 ditto	592	
	Ditto of 1 do. of 5 ditto	1,260	
	Outlet sluice of 8 do. of 5 ditto	8,215	29,016
F (1).—Other cross drainage works.	Drainage diversion cut	7,121	7,121
I.—Navigation works .	Terminal lock on the Bagda River	1,07,615	
	Ditto on Suburnrekha River	1,07,807	2,15,422
K.—Buildings . .	4 Temporary shelter sheds at R1,250 each	5,000	
	Portion of cost of head-quarter office and store godown . .	4,000	9,000
L.—Earthwork . .	Excavation of canal	3,74,336	3,74,336
	Total Canal, Range No. III .	...	7,09,012
	Range IVA.		
A.—Preliminary . .	Preliminary expenses	2,000	2,000
B.—Land . . .	Cost of land	16,963	16,963
D.—Regulators . .	Supply sluice of 10 vents of 5 feet each	10,649	10,649
F.—River and hill torrent works.	3 Inlet sluices of 2 vents of 5 feet each at R1,856 each . .	5,568	
	Inlet sluice of 3 vents of 5 feet each at R1,856 each . .	2,464	
	Ditto of 5 do. of 5 ditto at „ 1,856 do. . .	3,680	
	Outlet sluice of 3 do. of 5 ditto at „ 1,856 do. . .	4,422	
	Ditto of 5 do. of 5 ditto at „ 1,856 do. . .	6,640	22,774
F (1).—Other cross drainage works.	Drainage diversion channels	20,212	20,212
H.—Escapes . . .	Flood escape of 600 feet	1,200	
	5 Ditto of 1,000 „ at R2,000 each	10,000	
	1 Ditto of 1,000 „ at „ 2,400	2,400	13,600
I.—Navigation works .	Terminal lock on the Suburnrekha River	1,07,807	
	Ditto on the Panchpara River	1,19,457	2,27,264
K.—Buildings . .	3 Temporary shelter sheds at R1,250 each	3,750	
	Portion of cost of head-quarter office and store godown . .	3,000	6,750
L.—Earthworks . .	Excavation of canal	3.08.096	3,08,096
	Total Canal, Range IVA .	...	6,28,308
	Range IVB.		
A.—Preliminary . .	Preliminary expenses	1,500	1,500
B.—Land . . .	Cost of land	8,317	8,317
D.—Regulators . .	Supply sluice of 10 vents of 5 feet each	10,649	10,649
F.—River and hill torrent works.	2 Inlet sluices of 2 do. of 5 ditto at R 1,856 . . .	3,712	
	1 Ditto of 3 do. of 5 ditto at „ 1,856 . . .	2,464	
	Outlet sluice of 10 do. of 5 ditto at „ 1,856 . . .	12,185	18,361
	Carried over .	...	

APPENDIX C.—(*concluded.*)

CLASSIFICATION.	DETAIL OF WORK.	Amount of estimate.	TOTAL.
	Range IVB.	R	R
	Brought forward .	...	...
H.—Escapes . . .	2 Flood escapes of 1,250 feet at R2,500 each	5,000	8,000
	1 Ditto of 1,500 do.	3,000	
I.—Navigation works .	Terminal lock on the Panchpara River	1,19,457	2,23,398
	Ditto on the Burrabullong River	1,03,941	
K.—Buildings . .	2 Temporary shelter sheds at R1,250 each	2,500	5,500
	Portion of cost of head-quarter office and store godown . .	3,000	
L.—Earthwork . .	Excavation of canal	1,37,318	1,37,318
	Total Canal, Range IVB .	...	4,13,043
	Range V.		
A.—Preliminary . .	Preliminary expenses	3,500	3,500
B.—Land . . .	Cost of land	35,021	35,021
F.—River and hill torrent works.	2 Inlet sluices of 3 vents of 5 feet each at R2,464 . .	4,928	56,703
	6 Ditto 2 do. of 5 ditto at „ 1,856 . .	11,136	
	1 Ditto 4 do. of 5 ditto at „ 1,856 . .	3,072	
	1 Ditto 8 do. of 5 ditto at „ 1,856 . .	5,504	
	2 Outlet sluices of 4 vents of 5 feet at R5,531 each . . .	11,062	
	3 Ditto 2 do. of 5 do. at „ 3,313 do. . . .	9,939	
	1 Ditto 3 do. of 5 do. at „ 3,313 do. . . .	4,422	
	1 Ditto 5 do. of 5 do. at „ 3,313 do. . . .	6,640	
H.—Escapes . . .	Flood escape of 400 feet	800	14,000
	2 Ditto of 600 do. at R1,200	2,400	
	4 Ditto of 1,000 do. at „ 2,000	8,000	
	1 Ditto of 1,400 do. at „ 2,000	2,800	
I.—Navigation works .	Terminal lock on the Burrabullong River	1,03,941	2,10,662
	Ditto on the Metai River	1,06,721	
K.—Buildings . .	6 Temporary shelter sheds at R1,250 each	7,500	18,000
	Portion of cost of head-quarter office and store godown . .	5,000	
	Inspection Bungalow	5,500	
L.—Earthwork . .	Excavation of canal	5,75,749	5,75,749
	Drainage and Protective Work.		
L.—Earthwork . .	Embankment on the right bank of the Burrabullong River. .	7,112	7,112
	Total Canal, Range V .	...	9,20,747
	GRAND TOTAL WORKS .	...	26,71,110

J. C. VERTANNES, C.E.,
Executive Engineer, Balasore Survey Division.

Memorandum by Major J. M. Heywood, R.E., Superintending Engineer, South-Western Circle, on the Orissa Coast Canal.

The work to be carried out is to connect the terminus of the Hidgellee Canal at Kaleenuggur with the Metai River.

2. The different portions of the canal connecting the rivers which are met with while skirting the coast are numbered in continuation of those reaches actually constructed and known as Ranges I and II of the Tidal Canal.

Range III, 31¼ miles long, connects the Bagda River with the Suburnrekha.

Range IV, sub-divided into Ranges IVA and IVB, 23½ miles long, connects the Suburnrekha with the Panchpara and Burrabullong.

Range V, 38 miles in length, connects the Burrabullong with the Metai.

The total length of the proposed canal is 92¾ miles.

3. The proposed works are simply canals with level beds provided with terminal locks where the rivers are intersected. From December to May the canals will be fed by the tidal water of the different rivers. During the monsoon the supply will be kept up by the admission of the drainage water intercepted by the canals.

4. Range III will most probably start from the Bagda River at Baintghur where the river has a surface breadth of 300 feet at low-water and a depth of 20 feet.

Baintghur is opposite Kaleenuggur, the terminus of Range II of the Tidal Canal.

The line will follow that marked in dotted yellow on sheet 3, Book 1, and in continuous red from mile 12 to the junction at the Goocheeda River, about a mile above the point of meeting of that river with the Suburnrekha. The alteration at starting is recommended, as the nullah known as the Contai Nullah at Contai and the Surpai River below is rapidly silting up, and the drainage at Contai is becoming yearly more and more deteriorated, so that the closure of the river to tidal influence becomes a matter of necessity.

The southern terminus of this range is fixed in the Goocheeda River, as the Suburnrekha overflowing its banks during the rains requires a wide space for its spill water, and has necessitated the retirement of the left side embankments within the last 20 years to the east of the Kalaburia village (Book 1, sheet 9). The Goocheeda River is a well-defined channel, with a width of stream at low-water of 18 feet, and has not during the last 13 years shown any signs of deterioration.

5. The termini of the other ranges have been arranged as described in paragraphs 10, 11 and 12 of Mr. Vertannes's report.

6. The bed-levels of the proposed canals have been determined with reference to the average spring flood tides of the cold season when the rise of the tides is least. For, though the drainage water is the source of supply during the rains, its level is always higher than that of the tidal water, so that it is only necessary to fix the bed-level with reference to the latter.

7. The minimum depth of water in the canal has been fixed at 7 feet, as the draught of the largest description of boats expected to navigate the canals will be from 6 feet 3 inches to 6 feet 6 inches.

8. To ensure this supply it is necessary to determine—

1st—The evaporation from the surface of the water.
2nd.—Leakage through lock and sluice gates.
3rd.—Loss by lockage.

9. The loss by evaporation has been taken at ⅛th of an inch in the 24 hours according to actual experiments recorded in the Burdwan District during the cold weather, where the climate is very similar to that of the country traversed by the canals. The leakage through the lock and sluice gates has been assumed to be at the rate of a continuous discharge of 4 cubic feet per second in the 24 hours. The soil is generally very impervious to water, so that little or no leakage through the bank is expected.

The loss by lockage has been determined in the following manner:—

It has been found by actual experience that, in a lock 150 feet long from sill to sill and 20 feet between chamber walls, boats of an aggregate tonnage of 50 tons can be accommodated. According to the calculations in paragraph 21 of Mr. Vertannes's report, each lock full of water in Range III, for instance, after deducting the displacement of 50 tons is 16,920 cubic feet, and as the locks are supposed to be worked 40 times in 24 hours, the loss by lockage in the range will be 1,353,600 cubic feet.

The average spring flood tide in the cold season has been found to be—

110 feet in Range III,
109 ditto IVA,
109 ditto V,

and the reduction by the three causes of loss of water where the base is 50 feet is 1·44 feet in the period between two successive spring tides in Range III, 1·97 feet in Range IVA, and 1·02 in Range V.

In Range IVB the bed-level has been fixed with reference to the neap-tide level, as the length of the range is too short to admit of a sufficiently large supply being taken in at the period of spring tides to keep up the supply till the occurrence of the next spring. The average neap flood tide is 106·00, and the correct level of the bed should have been 99·00; but in Ranges IVA and IVB, the beds have been carried down one foot lower to provide against any silt which may be brought into the canal when the inundation water of the Suburnrekha or the Burrabullong River cross it.

The resulting bed-levels are in—

Range III	101·50
„ IVA	99 00
„ IVB	98·00
„ V	101·00

10. The bottom width of the canals was at first fixed at 40 feet, but owing to the necessity for raising the side banks in several places above flood-level, and for increasing the width near the terminal locks for a distance of about 2 miles, rendered advisable where heavy traffic is expected, the mean bottom width of the several ranges is considerably more.

The following table gives widths in the two cases of a canal with minimum bottom widths of 40 and 50 feet :—

NAME OF RANGE.	BASE 40 FEET.		BASE 50 FEET.	
	Minimum base.	Mean base.	Minimum base.	Mean base.
Range III	40	50·00	50·00	56·00
„ IVA	46	56·08	46·00	56·08
„ IVB	36	40·00	46·00	50·00
„ V	40	43·30	50·00	51·25

In the first case, in Range IVA, the bottom width has been raised to 46 feet to provide for sufficient earth for the raising of the side banks above flood-level.

In range IVB the minimum depth of water is 8 feet instead of 7 feet, so that the diminution in base does not affect the water area, as compared with that in the other ranges. In the second case, where the minimum bottom width is assumed at 50 feet, the minimum width in Ranges IVA and IVB has been fixed at 46·00 feet. As there is, however, one foot more in depth of water in these ranges than in the other, the real breadth is 49 feet.

11. The ratio of side slopes in all cuttings has been fixed at 1½ to 1, as the soil is found quite stiff enough to stand at that slope.

In all fittings the ratio of the slopes is 2 to 1, except where the side banks are to form protective embankments. In such cases the side slopes on the side facing the inundation water will be 3 to 2.

Where the side banks are exposed to the inundation waters of the streams intersected by them they will be raised 3 feet above the level of the flood waters. The crest will be 8 feet, and side slopes 2 and 3 to 1 on the canal and inundation sides respectively.

In Range III the side banks for the first seven miles have been raised above the level of the cyclone-wave of 1874. From the Tookee cross embankment to Sursuthipur, the north side embankment has been raised above the flood-level of 1868.

In Range IVA the portion of the canal between the terminal lock and the Toolsa Pat northern border embankment has its side bank on both sides of it raised above the flood-level of the Suburnrekha. The remaining portion of Range IVA, as well as IVB, have the side banks raised above the level of the inundation waters crossed by the canals. In Range V the side banks are everywhere raised three feet above flood-water level.

The width of tow-path in all the ranges has been fixed at 6 feet, and the height above water-level about 3 feet, except at times of excessive floods, when the level will be 18 inches in Range III and 6 inches in Range V. In Ranges IVA and IVB, for about three or four days in every ten or twelve years, the tow-paths will be submerged about 18 inches.

12. The supply of water to the canals during the rains, it has been stated in paragraph 3, will be from the intercepted drainage water, and this will be effected through various inlet sluices proposed to be constructed in the up-stream side bank of the canal.

From statements A and A¹ it will be seen that 1,880,762 cubic feet is the greatest probable loss of water per diem in any reach of the canal; and even if this is increased to 3,000,000 cubic feet, the supply necessary would only amount to 35 cubic feet per second in the 24 hours; this can be provided throug the half waterway of a single span of one of the inlets.

During the cold season the canals will be fed from the tidal waters of the different rivers, but, as in practice it is found that such water admitted through the lock brings a heavy deposit of silt, it is proposed to introduce the water through sluices.

13. In the sluice designed for Range III and part of Range IV (sheets Nos. 1 and 2, Book II), the floor has been placed three feet below the level of the ordinary spring tides, with the expectation that the upper waters being less charged with silt, the trouble now experienced from the heavy siltage in tidal canals may be avoided. During the months of March, April, and May, when the spring tides rise two feet higher, balks will be dropped into grooves, and the level at which the water will be allowed to enter the canal regulated accordingly.

14. In statements F and H, Mr. Vertannes has calculated out for Range III the waterway required for the proposed supply sluices on the Bagda River, and applies the calculations to the other ranges, as the tides in the Russulpore River have almost the same range as in the other rivers.

15. The supply sluice for Range III will be situated on the Bagda River, as the tide in the cold weather rises one foot higher than in the Suburnrekha, and the inundation from the latter river would render any sluices constructed on it much more expensive. An existing sluice in the Government embankment at Burtona will be remodelled and turned into a supply sluice.

For Ranges IVA and IVB the supply sluice has been placed on the Panchpara River, as the water from that river is more free from silt than that of the Burrabullong, and use will be made of the outlet and inlet sluices.

For Range V the water will be supplied through the proposed outlet sluices. In this case the water will be obtained directly from the sea by the different tidal creeks intersected by the canal.

16. In the statements marked E E are shown the depths of water in the different ranges during the cold season.

NAME OF RANGE.	BASE 40 FEET.						BASE 50 FEET.					
	AVERAGE SPRING TIDE.			LOWEST SPRING TIDE.			AVERAGE SPRING TIDE.			LOWEST SPRING TIDE.		
	Maximum.	Mean.	Minimum.	Maximum.	Mean.	Minimum.	Maximum.	Mean.	Minimum.	Maximum.	Mean.	Minimum.
Range III	8·5	7·725	6·95	7·50	6·96	6·43	8·50	7·78	7·06	7·50	7·00	6·50
" IVA	10·00	9·015	8·03	9·00	8·35	7·70	10·00	9·015	8·03	9·00	8·35	7·70
" IVB	11·00	9·50	8·00	10·00	9·00	8·00	11·00	9·50	8·00	10·00	9·00	8·00
" V	8·00	7·48	6·96	7·00	6·635	6·27	8·00	7·49	6·98	7·00	6·67	6·34

The average depth during the cold season may be taken to be 8 feet, and during the remainder of the year 10 feet.

17. The minimum depths in Nos. III and V will only be experienced once or twice during the 12 months, and will only last a day or two in a tide. The average minimum mean width of the proposed canal at the water-surface will, during the cold season, be 64 and 74 feet, and the average minimum mean width during the rest of the year 70 or 80 feet, according as the base of the canals is fixed at 40 or 50 feet.

18. The drainage intercepted by the canals will be described range by range.

RANGE III.

19. The principal drainage is that discharged into the Peechabunee khal from the low tract of paddy-land known locally as the Doobdah jheel. This jheel collects the drainage water over an area of 114 square miles, and is drained partly by the Peechabunee khal directly into the sea and partly by the Baliaghye khal into the Bagda River.

The former drainage intercepted by the canal, and the portion of the jheel in which the drainage accumulates, and which drain towards the Peechabunee khal is 14 square miles in area. After a heavy fall of rain the level of the accumulated drainage water in the low tract is raised to 112·50, andi t is found that drainage across the canal must be provided to draw off 4 inches in depth over this area of 14 square miles in 24 hours.

The Baliaghye khal is of sufficient size to pass off the drainage accumulating in the northern portion of the Doobdah jheel, but is not of sufficient capacity for the whole, and the cost of diverting the whole of the drainage would be in excess of the cost of the work now proposed, as it would entail drains through the jheel, the reconstruction of a bridge on the Contai and Midnapore Road, the improvement of the Baliaghye khal, and works for excluding the salt-water tides from entering the jheel.

The reduction of 4 inches in depth over 14 square miles represents a discharge of 1,500 cubic feet per second, and is provided for by an inlet sluice of 12 vents of 5 feet each on the north bank, and an outlet sluice of 8 vents of 5 feet each in the south bank of the canal.

The area of each opening of the sluices is 24 square feet, and the discharge is provided for by allowing a head of 1 foot on the inlet sluices and 2 feet on the outlet sluices; this will allow of a discharge of 1,450 cubic feet per second. Such a discharge will only be required once in every 5 or 6 years at the outside; ordinarily the discharge will only be one-fourth of this.

20. There are three other points where drainage is intercepted :—

1st.—Drainage discharged by the Bamoonea, and Iktarpore khals, intersected by the canal in the first 7 miles of its length. This is provided for by a diversion cut leading into the Bagda River, the section of which has been fixed from what has been practically found to be sufficient in the cuts in Ranges I and II.

2nd.—Drainage intercepted by the canal in the protected area between the Government embankment intersected by the canal in the 7th and 12th miles. The drainage area is about 6 square miles, and is now chiefly drained through the Ankghurra sluice. The inlet sluice in the canal, through which it is proposed to pass the drainage, will be of sufficient size to discharge a flow of 2 inches over the drainage area in the 24 hours, or 330 cubic feet per second under a head of 1 foot, so that an inlet sluice of 3 vents of 5 feet will suffice.

An addition to the estimate provides for an additional inlet sluice of 6 vents of 5 feet in the 12th mile of Range III, for the drainage of the Doobdah jheel.

3rd.—Drainage of a portion of the low lands in the Bhograi pergunnah within the Government embankment, as intersected by the canal in the 26th mile and at its southern terminus. The area amounts to about 6 square miles, and the drainage is admitted into the canal through two inlet sluices : one of 2 vents of 5 feet, the second of 1 vent of 5 feet.

The means of getting rid of the drainage which enters the canal are the lock sluices at the extremities, the outlet sluices into the Peechabunee khal and the Burtana supply sluice, and these will be, it is considered, sufficient.

RANGE IVA.

21. *1st.*—The drainage intercepted in the Soolsa Pat.

As the drainage is from land protected from inundation, inlet sluices into the canal are alone required, and these are provided with a waterway similar to that fixed for the existing sluices in the protective Government embankments.

2nd.—The drainage between the Soolsa Pát and the Panchpara river.

The ground in this tract is liable to be submerged by inundation spill from the Panchpara River and in extraordinary floods from the Suburnrekha in addition to the ordinary drainage of the adjacent lands.

It is proposed to provide for the drainage by catch-drains excavated nearly parallel to the line of canal as shown in sheets 11 and 12, Book I. The existing drainage khals between the new cuts will also be widened out and deepened.

It will be seen from sheets 4, 19 and 20, Book I, that a line of sand ridge runs along the coast line, which prevents the inundation water flowing to the sea, except through the channels of the Panchpara and Burrabullong rivers, and that on each side of the canal there is a considerable extent of low and level land, into which the inundation waters flow and pass off by the rivers which intersect the sand ridge. The extent of this area is shown by a blue dotted line on sheet 4, Book I, and it is found that ordinary floods which rise to 113·00 pass off the ground in 2 or 3 days, while extraordinary floods remain for 7 or 8 days. By extraordinary floods are understood the local floods, rising to a level of 116·00 feet, and floods increased by the Suburnrekha spill which rise to the level of 118·00. This being the existing condition of the country, it only remains to provide that the water shall rise in the tract between the canal and the sand ridge skirting the coast as rapidly after the canal is constructed as before, as the waterway left in the Panchpara and Burrabullong rivers between the terminal lock is amply sufficient for the actual discharge of the flood waters after once it has reached its maximum height.

The area of land subject to inundation, between the sand ridge and the line of the proposed canal, is about 60 square miles; the highest local flood is 116·00, and the average level of the country 111·50. The time taken by the water after once commencing to spill, before it reaches its maximum height, has been found to be from 36 to 24 hours. If 24 hours, to be on the safe side, is taken, the water-level rises 2¼ inches per hour, which is equivalent to a discharge of about 90,000 cubic feet per second.

To provide for this in Ranges IVA and IVB, flood-escapes to the extent of 6,800 and 4,000 lineal feet, respectively, besides the space between the terminal lock on the Panchpara and Burrabullong, have been left. The mean depth of water flowing across the spaces thus provided will be 2·25 feet, and the area of escape 44·500 square feet; so that, with a velocity of 2·5 feet per second, 111,250 cubic feet per second can be discharged, or upwards of 20,000 cubic feet in excess of that required.

When the Suburnrekha spills over its bank the floods rise over the 116·00 level to the level of 118·00. This occupies 12 hours; but, to be on the safe side, is assumed to take place in 6 hours, and is caused by a discharge of 154,860 cubic feet per second. The level of the tops of the escapes being 111·50, the mean depth of water passing over will be 5·5 feet, and taking the lineal feet of escape as before at 17,800 feet, the water sectional area will be 97,900 square feet, and the discharge, with a velocity of 2½ feet per second, 244·75 cubic feet, exclusive of that passed off by the two rivers (Panchpara and Burrabullong), which is greatly in excess of the requirements.

In paragraph 47 of his report, Mr. Vertannes calculates that, when the flood waters stand at 118·00, there will be an area of waterway in the flood-escapes of 115,700 square feet, sufficient to discharge 288,750 cubic feet of water, with a velocity of 2½ feet per second, and a flood area of 10,800 square feet, sufficient for a discharge of 54,000 cubic feet per second in the channels of the Panchpara and Burrabullong rivers, up to the level of 111·50. From 111·50 to 118·00 across the spaces left free between the terminal locks when the jungle has been cleared away, is included in the calculated area of 115,700 square feet given above. So that the total discharge will be 342,750 cubic feet per second during periods of extraordinary floods. The retarding effect of the tide in the two rivers is not taken into consideration, and its effect is also eliminated in calculating the sectional flood areas at the mouths of the rivers, as given in paragraph 47 of Mr. Vertannes's report. These are—

	Square feet.
Burrabullong River	17,417
Panchpara River	17,646
Bullong Khal	5,766
Gobri Khal	3,933
	44,762

With a velocity of 5 feet per second the discharge would be 223,810 cubic feet per second, or 118,940 cubic feet less than that provided across the canal and at the intersections with the Panchpara and Burrabullong rivers.

It seems to be unnecessary to discuss the question of the floods as affecting this portion of the canal any further, as if, in extraordinary floods, it should be found that additional waterway is required across the canal, it can be given, the openings metalled where the water passes being only estimated to cost Rs. 2 per running foot.

22. The level of the roadway of the escapes being placed at 111·50, *viz.*, the average level of the surrounding country, it is desirable to keep up the level of water in the canal as near as possible to the level of 111·50. In order to do this, inlet sluices are provided. The calculations are based on a surface-level of water in the canal in Range IVA of 108·00: 16 hours are assumed to be necessary for the raising of the water from 108·00 to 111·50, and the velocity is limited to 2½ feet per second.

The sluices will have an aggregate of 14 vents, the sills being placed at 107·00. The mean waterway of each will be 13·75 square feet, and the total 192 square feet; the discharge will be therefore 480 cubic feet per second, the amount required.

In Range IVB the same method of calculation is adopted, and the following data employed:—

Canal bed-level 98·00.

Level of water in canal reduced to 107·00, *viz.*, level of high-water of neap tides of monsoon.

Mean level in canal $\frac{111\cdot50+107\cdot00}{2}=109\cdot25$.

Length of range 6½ miles.

Water required to be admitted to bring the level up to 111·50, 12,934,350 cubic feet.

Time allowed 18 hours.

Discharge required through sluices, 200 cubic feet per second.

To perform this, sluices with 7 vents, 5 feet wide and 2·25 mean depth, are provided.

RANGE V.

23. The areas of the various drainages crossed by the Canal Range V are shown in sheet I, Book I, of the accompanying drawings.

The principal drainages are those discharged by the Kansbans and Talpudda nullahs. To the east of the canal a continous line of sand ridge, similar to that which fringes the sea coast to the east of Range IV, continues along the edge of the coast, and the drainage, as in the former case, breaks through at several points and empties into the sea. A survey of the sand ridge has been made, and the results are given in sheets Nos. 21 to 25 of Book I of the accompanying drawings.

The drainage area may be divided into two portions—

1st.—That portion between the Burrabullong River and the ridge between the Kansbans and Talpudda nullahs.

2nd.—The part between this ridge and the Metai River.

In the first part it is found that the period which elapses between the time when the inundation water begins to spill over the country till the maximum flood-level is attained, is from 36 to 24 hours.

The area of the inundated country between the coast and canal is about 10 square miles, and the depth of the inundation water about 5 feet; so that, assuming, to be on the safe side, that 24 hours is the period between the time of spilling and the period of maximum rise, a discharge of 16,140 cubic feet per second is required to inundate the 10 square miles of country to the depth of 5 feet. This is provided for by 3,000 running feet of flood-escape, and 300 superficial feet of waterway in the sluice openings.

The tops of the flood-escapes are fixed at 111·50, and the available area to high flood level 116·00 is 6,750 square feet, which, together with 300 square feet of water-way in the sluice openings, gives a total of 7,050 square feet, and a discharge of 17,625 cubic feet, with a velocity of 2½ feet per second at the top of the flood; with the same velocity, the discharge would be 35,000 cubic feet per second. The total area of the basin included in the drainage now under consideration is 180 square miles, and during great floods the discharge is 47,000 cubic feet per second in the 24 hours, or 255 cubic feet per second per square mile in the 24 hours. There is, therefore, a flow-off of over 9½ inches in depth in the 24 hours.

The second area between the Kansbans and the Metai rivers is inundated from both rivers, and during extraordinary floods spill water from the Byturnee finds its way into the Metai below the proposed terminus of the canal.

The area between the sand ridge and the canal, which is inundated from these various sources, is 6 square miles, and the time required to fill this area to the maximum level is found to be 24 hours. The average level of the inundated tract is 111·50, and the maximum flood-level 116·00, so that the discharge per second required to inundate it in 24 hours is 8,712 cubic feet per second. To provide for this, 2,000 lineal feet of escapes are provided for the Kansbans and Sychunpore nullahs, and 1,000 lineal feet for the Gummai nullah, giving a superficial area of waterway equal to 6,750 square feet, besides 225 square feet of inlet and outlet sluices; so that the total flood area is nearly 7,000 square feet, capable of discharging 17,500 cubic feet per second, or 8,800 cubic feet in excess of that required.

For the portion between the Gummai nullah and the Metai River a flood-escape of 1,000 feet has been provided. This may be found unnecessary, as it will be advantageous to divert as much water as possible into the Metai River, and thus assist in maintaining its present deep and well-defined channel.

24. The flood sectional areas of the streams which intersect the ridge on the sea coast to the east of the canal are as follows:—

	Sq. feet.
Talpudda nullah	1,047
Flow over banks	218
Jamca nullah	1,344
Flow over bank	2,538
Moisali nullah	553
Soondra nullah	694
Flow between banks	3,769
Total	10,163

in the first drainage portion capable of discharging 31,240 cubic feet per second. The escapes and outlets in the canal will discharge, as has been noticed before, at the top of the flood 35,000 cubic feet per second, or a flow-off of over 7 inches in depth in 24 hours per second, so that ample provision is made for the drainage across the canal.

In the portion of the canal between the Kansbans and Metai River the waterway allowed is as below:—

	Feet.
Flood-escapes for the Luchimpore and Kansbans rivers	2,000
Ditto for Gummai nullah	1,000
Ditto between Gummai nullah and Metai River	1,000
Total	4,000

The area of waterway at the highest floods is 18,000 square feet, which, together with 225 square feet in the outlet sluice vents, gives a total area of 18,225 square feet, sufficient to discharge 45,562 cubic feet per second.

The discharge through the nullahs intersecting the sand ridge is 37,325 cubic feet per second, or 8,237 cubic feet per second less than that provided across the canal.

It is to be noted that taking two calculations worked out,—1st, the discharge across the canal for 24 hours, while the inundation water is rising to its maximum, and 2nd, the discharge at the maximum,—the drainage across the canal in the first part is capable of passing off 9½ inches in depth of the drainage basin in the first 24 hours and 7 inches in depth in the second 24 hours, or 16½ inches over the whole basin in 48 hours. In the second part the depths will be 6 inches for the 48 hours over the whole basin of 400 square miles.

25. The inlet sluices have been chiefly designed, as in the other ranges, to feed the canal with drainage water, and to raise the canal water to the level of the top of the escapes before the inundation waters cross the canal. The number of vents provided is 30, which is 30 per cent. over the number actually required according to the calculation given in paragraph 59 of Mr. Vertannes's report. This is provided, as in a long reach of a canal of 38 miles it is not probable that the inlet sluices will all be discharging at the same time or to the same extent.

The outlet sluices for Range IVA consist of eight vents; their chief duty is to take in the tidal water during the dry season: for drainage purposes one-half of those provided would suffice. In Range IVB ten vents are estimated for, and 21 vents in Range V.

26. The description of the masonry works is given in paragraphs 62 to 83 of Mr. Vertannes's report. Some alterations have been made which are noted in the estimates and plans.

27. In paragraphs 84 to 91 the rates of work are discussed: those on which the chief expenditure will be incurred are masonry and earthwork. It is hoped that the price of the former will be much reduced by the adoption of wood-fuel as much as possible for coal in the burning of the bricks. The rates for earthwork are in—

Range III,	R 3·45	per 1,000	cubic feet.
„ IVA,	„ 3·90	ditto	ditto.
„ IVB,	„ 4·56	ditto	ditto.
„ V,	„ 3·90	ditto	ditto.
Average	3·82	ditto	ditto.

The mean depth of cutting in—

Range III is	8·83 feet.
„ IVA „	11·31 „
„ IVB „	13·22 „
„ V „	10·38 „

These rates are nearly 50 per cent. in excess of the rates which were in force in Ranges I and III of the Hidgellee Canal when they were being excavated some five or six years ago.

The cost of the extension to Range I was only at the rate of R2·62 per 1,000 cubic feet inclusive of all contingencies. The Bhograi embankment cost R 2·10 per 1,000 cubic feet, the banks being 14 feet high, and the earth taken from one side only.

The earthwork of the great sea dyke cost, six years ago, only R2·6 per 1,000 cubic feet, and the banks vary in height from 16 to 18 feet with an average base of from 130 to 140 feet. Mr. Walker, Superintending Engineer, Orissa Circle, in his letter No. 544 of 16th March 1878, recommended that a higher rate should be adopted for the earthwork of the projected canal. His rates, including contingencies, were as follows:—

For Range III, R	4·29	per 1,000 cubic feet.
„ IV, „	4·29	ditto.
„ V, „	4·40	ditto.
Average „	4·33	ditto.

Mr. Walker argues from the assumption that the circumstances will be the same in the projected canal as in the extension of the Kendrapara Canal to Jumboo. The former canal, however, runs through a district highly cultivated and crowded with villages; the other through a country of uninterrupted low jungle and waste land. The soil at Jumboo is of a soft and bad description, whereas that along the projected canal is stiff and impervious to leakage, so that pits 10 to 15 feet in depth can be sunk with almost vertical sides and with little or no leakage.

Soundings taken at the lock sites prove that springs are only met with in three instances, and in only two cases above the foundation-level. Out of 9 borings—

4	show stiff black clay.
1 „	soft ditto.
1 „	coarse sand.
1 „	clay with sand.
1 „	black clay with a little sand.
1 „	sand with a little clay.

The various objections urged against the construction of the canals are the following:—

1st.—Great leakage is expected from the sides of the canal channel due to the overflow of the tidal water.

2nd.—The cross drainage will, it is anticipated, not only wash the canal bank back into its channel, but also lead to large deposits of silt over its bed.

3rd.—Cyclones will, it is assumed, cause great damage.

28. As regards the first objection, soundings at the site of the principal proposed masonry works and along the line of canal prove that the soil is of a stiff nature, so impervious to water that pits are sunk to 10 and 15 feet without meeting water.

In excavating the first two ranges of the canals, known as the Hidgellee Canal, the Gowkhally lock pit was excavated to a depth of 26 feet, and a trial pit was carried 4 to 5 feet lower without finding water. The Etamugra and Terrapakea lock pits were excavated to a depth of 23 feet without meeting water, and the Kaleenuggur lock pit was carried down dry 24 feet; at the 25th foot a spring was met with which gave much trouble.

29. With reference to the second objection, the banks can only be washed in where they are low and weak, or where they cause such an obstruction to the flow of the intercepted drainage water across the canal as to accelerate the velocity above what the earth will stand.

In previous paragraphs it has been shown that if the calculations of flood discharges are correct, the construction of the canal will have no effect in retarding the filling up of the inundated area between the canal and the coast; the escapes provided being sufficient to pass the water across with no greater velocity than two and half feet per second, which would be no greater than the ordinary velocity in any irrigation canal in any other part of India, and would have no effect in washing in the earthen banks on either side of the escape, or in any other portion of the canal. If experience shows that more waterway is required, it will be easy to provide it at no greater cost than the cutting down of an additional length of the banks. The deposit of silt over the bed, by the constant passage of drainage water into and across the canal, is not to be compared with the deposition of silt from the entrance of tidal water required to feed the canal during the dry weather.

Specimens of the ordinary inundation water collected during the last monsoon at certain portions of the line show hardly any sign of silt. The stiff nature of the soil in the drainage basins, the extent of almost flat country on the up-stream side of the canal, the presence of numerous large tanks on the line of canal which for years have been submerged by the inflow of the inundation waters and have not silted to any extent, are all arguments against the probability of any great deposit of silt being experienced.

The greatest deposit likely to occur would be in Ranges IVA and IVB from extraordinary floods from the Suburnrekha and Burrabullong. These floods would, however, come down on a plain inundated to the depth of some four to five feet, and nothing checks silt with greater rapidity than a body of comparatively still water.

Mr. Vertannes, in order further to test the accuracy of his views, had sections taken in Ranges II and III of the Orissa High Level Canal, which was inundated by the flood waters of the Byturnee in 1877, when the floods breached the embankments, trunk road and canal side bank. The cross sections are shown in sheet No. 26 of Book I, and show that the normal bed of the canal was not affected by silt brought in. As the country above these two ranges of canals has generally a fall of 8 to 10 feet per mile, and the flood waters of the Byturnee are more likely to be charged with silt than those of the inundations which are likely to affect the coast canal, the fact is one of considerable value.

To meet any chance of silt being deposited, the canal bed level is lowered at the escapes and sluices, and Ranges IVA and IVB are cut down throughout a foot lower than that necessary to give a depth of water of 7 feet in the canal.

30. It has been stated above that the great cause for fear in a canal fed from tidal sources is the deposition of silt at such times as the tidal water is introduced into it.

The following shows the deposit of silt in the Midnapore and Hidgellee canals from this source alone.

In the Oolooberriah and Bansberriah reach of the Midnapore Canal, 1 foot for a mile at each end annually, and 6 inches in the intermediate five miles, 84 lakhs of silt having accumulated in seven years in a distance of a little over seven miles. In the Hidgellee Canal, first range, Hooghly end, between March 1874 and December 1877, 15 lakhs of silt were found in the first mile. In the first range, Huldee end, in one year 20 lakhs had accummulated in the first mile. In the second range, Russulpore end, 6 lakhs had accumulated in 21 months in the first mile.

It is, however, confidently expected that by feeding during the dry weather from the upper water of the tides through the feeding sluices, and during the rains from the inundation waters through the inlet sluices, that the chief siltage will only take place when the locks are opened to admit boats, and that the great expense of maintenance may be reduced to its lowest possible.

31. The third objection is that cyclones are likely to do much damage when they occur.

It will be seen from a reference to the index maps that the whole of Range III and the first nine miles of Range IVA are protected, and that in the remaining portions of the canals the continuous line of sand hills on the sea coast will afford sufficient protection. The only way by which the storm-wave can enter will be through the gaps, where the different drainages empty into the sea, and the area compared with that of the low country likely to be inundated is comparatively small.

It seems most probable, as a cyclone is always accompanied by heavy rain, the local inundation waters will stand at a depth of five or six feet over the country, and that the cyclone-wave will only add a couple of feet or so to that level.

Actual experience has, moreover, proved that the cyclone-wave, acting on the upper portion of the canal which has been completed and worked for some years, produced no greater damage than that entailing an expenditure of Rs. 248 in repairs. The wave passed over the lock gates of the second range of the canal, rising three feet over the lock coping, and traversed the canal from end to end. Any damage which was caused occurred through the bursting of the protective embankment on the Russulpore River. Twenty-three large breaches and numerous small ones having taken place, the water thus admitted struck the last bank of the canal with force between the 13th and 17th miles.

32. Attached to this report is a memorandum by Mr. Vertannes on a portion of the East Coast Canals in the Madras Presidency. Mr. Vertannes was deputed to visit the canals, in consequence of the remarks made in a memorandnm submitted by Colonel Sankey, dated 30th August 1878, in which it was stated that in 1856-57 a heavy downfall of 11 inches of rain having fallen within 24 hours, the sea level rose to such a height as entirely to prevent the free discharge of the rivers, which at the time coming down in flood could only expand into widespread inundations as they approached the coast. The effect on the canals being that where they passed through deep cutting, or where the side banks were sufficiently high, as they are generally throughout Cochrane's Canal, the flood merely deposited a certain amount of silt; but where the canal had been led along the depression which generally exists parallel into and behind the coast line of dunes, and the side banks were consequently low and weak, long stretches of these were washed bodily into, and almost filled in, the channel.

Mr. Vertannes is of opinion that the silting up of the canal, known as Cochrane's Canal, is explained by the following :—

1st.—The soil through which the canal is excavated contains a very large proportion of sand.

2nd.—The drainage intercepted by the canal flowing over a sandy and loose soil was allowed to flow into the canal with an increased velocity through a few open sluices, with floors inclined towards the canal bed.

3rd.—The drainage of a considerable portion of the town of Madras was discharged into the canal.

He also states that the flood-water from the river (Corteliar) could not have introduced the silt, as the lagoons into which it has had free access for ages have remained deep and unsilted; and he considers the silting was caused by the washing in from the banks, caused by the heavy rain acting upon sandy banks left unturfed. An inspection of the existing bank leads, moreover, to the belief that silt cannot be deposited in any quantity, as the banks seemed to be of less section than when originally thrown up, which is hardly likely to be the case if any quantity of silt has been taken out since the canal was originally excavated.

Where the banks were washed into the canal the cause was due, according to Mr. Vertannes, to the insufficient height and sections of the banks, and this is corroborated by the fact that where the canal is in shallow cutting, the west bank has disappeared altogether, whereas the east bank exists to this day in the same state as it was originally thrown up.

33. As a portion of Mr. Vertannes's duty, when reporting on the Madras Coast Canal, was to find out whether the conditions of that canal and of those projected by him were similar, the following comparisons are given :—

Name of Canal.	Bed level.	Bottom width and ratio of side slopes.	Nature of soil.	Rise and fall of tides	DEPTH OF WATER IN CANAL.		Whether open cuts are provided with terminal locks.
					Maximum.	Minimum.	
				Feet.			
Madras Coast Canal . .	Three feet below low-water level.	30 feet and 2½ to 1.	Generally clay mixed with a large proportion of sand, &c.	1 to 2	6 to 7	3 to 4	Open cut.
Proposed Orissa Coast Canal.	Five feet below low-water level.	50 to 56 feet, and 1½ to 1.	Stiff alluvial clay .	12 to 16	10 to 12	7 to 8	Provided with terminal locks.

The canals have but little in common. In the Madras Coast Canal the sandy nature of the soil is the cause of much trouble and expense, the tidal water is nearly free of silt, and masonry works are not required.

In the Orissa Coast Canal, on the other hand, the soil is stiff clay, the tidal water is heavily charged with silt, and extensive masonry works are required.

34. The estimate of the cost of the Orissa Coast Canal is detailed below:—

	R
Preliminary expenses	10,000
Land	1,07,906
Regulators	44,810
River and hill torrrent works	1,89,787
Navigation works	8,76,746
Buildings	39,250
Earthwork	14,02,611
TOTAL . .	26,71,110
Establishment, 25 per cent.	6,77,778
Tools and plant, 4 per cent.	1,06,854
TOTAL . .	34,45,742
Interest at 7 per cent.	2,41,201
Pensions, 20 per cent. on establishment	1,33,555
Capitalised value of loss of Government revenue	23,000
GRAND TOTAL . .	38,43,498

This gives a rate per mile as below:—

Cost of works	28,799·03
Establishment at 25 per cent.	7,199·70
Tools and plant at 4 per cent.	1,152·07
Indirect Charges.	
Interest at 7 per cent.	2,600·50
Pensions	1,439·99
Capitalised value of Government revenue	247·98
TOTAL . .	41,439·27

or in round numbers, Rs. 41,440 per mile.

35. In letter No. 1821, dated 3rd August 1878, the Deputy Secretary to the Government of India, Irrigation Department, draws a comparison between the cost of the new ranges in the Orissa Coast Canal and that of the first two ranges known as the Hidgellee Tidal Canal.

36. This canal is 28 miles long, and cost as follows:—

	R
Works, &c.	12,66,239
Establishment	4,49,790
Tools and plant	57,585
Interest	6,05,992
Capitalised value of Government revenue	11,206

the total cost being, after the deduction of R915, receipts on capital account, R23,89,897, or R85,353 per mile.

Colonel Haig has, however, pointed out in his letter No. 3355I. of 23rd August 1878, to the Secretary to Government of India, Public Works Department, that the following sums should be deducted:—

R2,42,000, three years' interest on capital outlay after completion,

„ 1,87,195, bonus paid to the Irrigation Company, when the works were taken over by Government,

„ 52,358, spent in silt clearance,

„ 1,50,000, difference between a charge of 25 per cent. on works for establishment and actual expenditure debited to that head by the Company,

or a total of R 6,31,553.

	R
If this is deducted from R 17,72,999, the actual cost of all works debitable to the budget grant, the balance becomes	11,41,146
7 per cent. interest is	79,880
Pensions, 20 per cent. on establishment (R2,99,790)	59,958
Capitalised land revenue	11,206
Total	12,92,190

or Rs. 44,006 per mile.

37. It has been stated above that the present estimates for Ranges III, IVA, IVB, and V amount to R38,43,498, or R41,439 per mile. It would, however, be well to fix the estimate at 40 lakhs to cover any contingencies which may arise; the rate will then be R43,010 per mile. The annual interest and maintenance will be—

	R
40 lakhs, at 4½ per cent.	1,80,000
Maintenance of 93 miles, at Rs. 800 per mile	74,400
Total	2,54,400

The cost of the maintenance is deduced from the actual expenditure in the Hidgellee Canal, which in the five years ending 1877-78 cost R1,03,855, or R20,771 per annum, being a mileage rate of R742.

38. The income is estimated by Colonel Haig in his note, dated 15th February 1878, at from R26,00,000 to R3,30,000, exclusive of receipts from miscellaneous sources.

These returns are made up in the following manner:—

	R
Revenue from goods traffic	1,61,579
Ditto from passengers	76,135
Ditto from 9,34,000 maunds of goods now sent by land from Balasore to Baliaghye	22,600
Total	2,60,314

The receipts will, therefore, cover the cost of maintenance, and yield 4½ per cent. on the capital expended.

39. There is also a fair expectation of the receipts exceeding those given above.

Mr. Vertannes in his statement omitted all mention of the carriage of salt, but Mr. Norman, the Collector of the Balasore District, anticipates a considerable traffic, even if the Balasore salt holds its grounds against the introduction of Liverpool salt. Mr. Norman, however, in his No. 1369 of 12th March 1868, states that "the manufacturers are unanimously of opinion that imported salt will be enabled by the opening of the canal to drive the Balasore salt out of the market;" and in a previous letter No. 938 of 6th November 1877, in discussing the passenger traffic, considers that Mr. Vertannes's estimate of 100,000 passengers should be at least doubled; this latter will add another R70,000 to the receipts.

Mr. Harrison, Collector of Midnapore, also in his letter No. B of 18th October, estimates an additional revenue of R10,000 or R12,000 from miscellaneous sources, such as licenses to fish, sale of grass of banks, &c., so that the higher income assumed by Colonel Haig is quite within the range of expectation.

The real importance of the canal, however, lies in the necessity of opening up some line of communication with Orissa which may be depended upon at all seasons, by which the boats plying in the rivers of Bengal may be able to proceed safely to the places of import and export, the ports of Orissa being almost closed for two-thirds of the year to sailing vessels. This has been discussed by Colonel Haig in paragraphs 24 to 31 of his note of 15th February 1878.

J. M. Heywood, *Major*, R.E.,
Supdg. Engr., South-Western Circle.

Note on the proposed Orissa Coast Canal by H. C. Levinge, Esq., Chief Engineer, Public Works Department, Irrigation Branch, Bengal.

General description.

The Coast Canal, plans and estimates of which are now submitted in the fullest detail, is designed to connect the Hooghly with the rivers and canal system of Orissa. The line will skirt the coast from the end of the present Tidal Canal at the Russulpore River in Hidgellee, and terminate in the Metai, a deep tidal river in direct communication with the Dhamra, whence navigation is open *viâ* the Gobri Canal to Cuttack, and by tidal creeks to False Point. A moderate outlay in improving the creeks south of False Point and in opening out a few new cuts would bring the Chilka lake and Ganjam into communication with Calcutta, and thus connect the large towns and marts marginally noted; but this question belongs to the Orissa scheme, and will not be discussed here.

Calcutta.	Chandballi.
Balighal in Hidgellee.	Cuttack.
Balasore.	Pooree.
	Ganjam.

High Level Canal.

2. Before entering into details of the project now submitted, a few words must be said on the subject of the completion of the High Level Canal, which was originally designed by the East India Irrigation and Canal Company to connect Calcutta with Cuttack. From Bhuddruck, near which town the canal now ends, to the junction with the Midnapore Canal, the distance is 134 miles, divided into two sections—

	Miles.
(1) Bhuddruck to Balasore	50
(2) Balasore to the Midnapore Canal	84

The first section has been laid out and estimated in detail. The cost, according to Mr. Vertannes, Executive Engineer, would be 43½ lakhs of rupees, while the estimates for the second portion, based on the most reliable data of cost of similar works already constructed, or estimated for in detail, would be 53¼ lakhs, making a total of 96¾ lakhs for works only, or 145 lakhs, inclusive of book charges. The very lowest estimate for the first portion, that is, from Bhuddruck to Balasore, amounts to 31½ lakhs, while the estimates now submitted for the whole Coast Canal to connect the Hidgellee Canal with the Metai are 36 lakhs. It appears to me to be unnecessary to say anything more on the subject; but if it be urged in favour of the High Level Canal that it will afford irrigation as well as navigation, I would refer to a note by Colonel Haig, dated 5th October 1877, in which it is shown that the interest on the expenditure on distributaries alone, which are not included in the estimates of the canals above given, would no more than cover the water rates. I think this disposes of the question of the High Level Canal as an alternative line,—for the present at all events.

Link line, Bhuddruck to the Metai.

3. It has been stated, however, that the High Level Canal from Cuttack at present "terminates abortively in a paddy-field." This is true, and the question has been discussed whether it would not be desirable to connect it with the proposed Tidal Canal by a link from Bhuddruck to the Metai. I believe it will be worth while to do so eventually. The discussion of this point may, however, be postponed for the present. An approximate estimate for this link has been prepared by the Superintending Engineer, Orissa Circle, amounting to 10 lakhs, without book charges.

Division of Coast canal into ranges.

4. The canal which it is now proposed to construct is divided into lengths or ranges as follows (the numbering of the ranges is in continuation of the two already made and termed the Hidgelee Tidal Canal) :—

	Miles.
Range III—Connects the Bagda River, a branch of the Russulpore in Hidgellee, with the Subunrekha in Balasore	31¼
Range IVA—Between the Suburnrekha and the Pachpara rivers in Balasore . .	17
Range IVB—Between the Panchpara and the Burrabullong rivers near Balasore . .	6½
Range V—Connects the Burrabullong with the Metai in Balasore	38
Total .	92¾

Each of these ranges will be simply an open cut with level bed, provided with a lock at each end. During the dry season they will be filled by the tides, and during the rains by surface drainage from the adjoining country; and, as will be seen further on, full provision has been made for passing all drainage which would otherwise be intercepted.

General alignment.

5. The canal has been laid out generally parallel to the great line of sand-hills, which, as will be seen in the accompanying plans, extends uninterruptedly (except at the mouths of the rivers) along the whole coast from Contai in Hidgellee to the Dhamrá; thus the canal is to a great extent protected from injury during the occurrence of cyclones, the wave being confined to the rivers.

Alignment of Range III.

6. An alternative alignment has been proposed at the commencement of Range III, as it is in contemplation by the revenue authorities to reclaim by embankments the 'Julpi,' or old salt lands, colored green on the plan (sheet III of Book 1), in which case the diminution of tidal flow would inevitably cause the Badga creek to silt up. I am of opinion that it will be best to construct the lock at Baintghur, opposite Kaleenuggur, the terminal lock of Range II, and to lay out the canal in the direction of the yellow dotted line on the map, utilizing a portion of the creek between Surpai and Contai, and building a drainage sluice at its mouth. By this arrangement the length of the canal will be increased three miles; but a saving of two miles of excavation will be effected. If the lock is built at Surpai, as proposed by the Executive Engineer, and hereafter the inundated lands are reclaimed, there will, I am confident, be much trouble in keeping the creek clear as far as Surpai. This alternative scheme is noticed by Mr. Vertannes in the 6th paragraph of his report. No alteration is required in the estimate, as the change will effect a slight saving, if anything, Range III terminates in the Goocheeda River, which falls into the Suburnrekha about one mile below the point selected for the lock side. The Goocheeda drains a large area of country, and is not likely therefore to deteriorate. The width of the stream at low water is 180 feet, and its depth 12 to 15 feet. The position of this lock has been judiciously chosen.

Alignment of Range IVA.

7. The alignment of the greater part of Range No. IVA is between two great ranges of sand-hills, in the tract known as the *Toolsa Pat*; the canal is thus thoroughly protected on the east and west, while inundation is excluded on the north and south ends by existing embankments. After passing this 'pat,' the line traverses a low tract of country subject to inundation from the Panchpara River, and occasional floods from the Suburnrekha.

Alignment of Range IVB.

8. Range IVB also traverses a low country, quite flat and subject to inundation. The positions of the locks call for no remarks. It may be asked why the southern terminal lock of Range IVB and the northern terminal lock of Range V were not placed nearer to the town of Balasore; the reply is that the high ground comes down on the right bank nearly to the lock site, and that to have placed it further up would have involved heavy cutting. The drainage, which finds its way into the Burrabullong on the left bank above the lock site, would have caused difficulty. For these reasons I think the Executive Engineer has chosen wisely. The distance by river, which is deep and wide, from the canal crossing to the town of Balasore is four miles.

Alignment of Range V.

9. The line of canal in Range V, after leaving the Burrabullong, trends towards the coast to avoid high land, and thence runs nearly straight to the Metai. Four rivers are crossed—the Gummai, Prag, Talpudda, and Kansbans. Between the two last there is a ridge, involving from 10 to 15 feet cutting, which, however, cannot be avoided. The southern terminal lock of the fifth range has been placed at a point on the Metai where that river is 130 feet wide at low water, with a depth of 10 to 15 feet; thence it gradually becomes wider and deeper until it joins the Brahminee near Dhamra.

10. The draft of the largest boats that are likely to navigate the canal is 6¼ to 6½ feet; the minimum depth of water in the canal has therefore been fixed at 7 feet, and the bed level in the different ranges must be arranged accordingly. In order to determine this, the following points have been taken into consideration :—

Determination of bed level.

(1) Level of source of supply.

(2) Loss of water, by—

  (a) Evaporation;

  (b) Leakage through locks and sluices ; and

  (c) Lockage.

(3) Surface area of each range.

As already stated, the canal will be filled in the dry season by the tides, and in the rains by the surface drainage of the country; and as the latter is always higher than the former, the supply from the tides only need be taken into consideration. The Executive Engineer states that by actual experiment at Burdwan, the loss by evaporation was found to be $\frac{1}{6}$ inch in 24 hours; on the coast, then, it is not likely to be more. For loss by leakage, the Executive Engineer assumes 4 cubic feet per second in each range; and as the soil is very retentive, this may be accepted. For loss by lockage, the contents of 80 locks, 40 at each end, daily have been taken, from which must, however, be deducted the displacement of the boats; usually several will pass through the locks together, the allowance therefore seems to be sufficient.

11. As regards the width of the canal, I am decidedly of opinion that the minimum of 50 feet base should be adopted; the difference of cost between this and a canal of 40 feet base is only Rs. 1,21,000, and for steam navigation a wide canal is unquestionably best. The ratio of side slopes has been taken at 1½ to 1, the soil throughout being exceedingly stiff. The data having been thus determined, the calculation for bed level is simple, as follows :—

Width of canal base and calculation of bed level.

Range III.—31¼ miles.

Loss by evaporation, $\frac{1}{6}$ inch daily.

Average spring tide level	110·00
Assumed lowest canal level	108·50
	2)218·50
Mean surface level	109·25
Bed level	101·50
Mean depth	7·75

Side slopes being 1½ to 1 and base 50 feet, the surface width will be—
2 (7·75 + 3·875) + 50 = 73·25 feet; then 73·25 × 31·25 × 5,280 × $\frac{1}{72}$ = 167,864 cubic feet daily loss, or for ten days = 1,678,640 . . . . (1)

Loss by leakage—
4 cubic feet per second = 345,600 per day, or for ten days = 3,456,000 . . (2)

Loss bg leakage—

Mean level of water in canal	109·25
Ditto ditto in river	103·50
Depth in lock	5·75

Contents of lock—155 × 21 × 5·75	= 18,715
Deduct displacement of 50-ton boat—50 × 36	= 1,800
	16,915

and 16,915 × 80 (number of locks full) = 1,353,000 daily, or for ten days 13,532,000 . . . . (3)

The total loss in ten days' interval of tides will therefore be —

(1) Evaporation	1,678,640
(2) Leakage	3,456,000
(3) Lockage	13.532,000
Total cubic feet	18,666,640

and as the average surface area is 73¼ × 31¼ × 5,280 = 12,086,222, the actual depth drawn off will be $\frac{18,666,640}{12,086,222}$, or 1½ feet nearly. The water level being 110 — 1·50 = 108·50, and the minimum depth 7 feet, the bed level of Range III should be 101·50.

Bed levels.

12. The Executive Engineer, in his report and accompanying statements, shows that the levels in the different ranges must be as follows :—

Range III	101·50
„ IVA	99·00
„ IVB	98·00
„ V	101·00

In Ranges III, IVA, and V these levels have been determined with reference to average spring tides in the cold season, recurring at intervals of ten days; but it must be remembered that only for eight or ten days in the year, that is, during the tides of December, January, and February, will the water fall so low as seven feet. During the rest of the year the tides will be higher. In Range IVB the bed level has been fixed with reference to neap tides, because the consumption of water in so short a reach would lower the surface so rapidly that before the recurrence of spring tides the depth would be reduced below the minimum required. In this range only has the minimum been fixed at eight feet instead of seven; this is, I think, a prudent precaution; because from the more frequent admission of tidal water, the tendency to silt will be greater.

Level of lock sills.

13. The levels of lower sills of locks had been fixed by Mr. Vertannes at four feet below lowest water of spring tides, so as to allow of steam navigation being carried on at all times of tides; but after carefully considering this point, I have come to the conclusion that it will be sufficient to fix them at two feet below lowest tidal water, for the following reasons :—*First,* to take an extreme case, if a steamer drawing, say three feet, were to arrive at a lock when the tide was falling, and only three feet on the sill, she would have to wait till the water fell, and rose again to three feet—this would be somewhat under two hours—and if she were thus detained at one lock, she could not be again detained on the same day at any other lock, Balasore being the halting place; moreover, this possible detention could only occur at lowest spring tides. *Secondly,* very great difficulty has been experienced in keeping the entrance to the lock clear of silt to four feet below low water. *Thirdly,* on the ground of economy and facility of construction, there are obvious advantage in placing the sills at the higher level.

Level of coping of locks.

14. The levels of the coping of the locks at the Panchpara, Burrabullong, and Metai, which has been fixed by the Executive Engineer at one foot above the maximum flood levels of those rivers, have been lowered three feet, four feet, and four feet respectively. There is no advantage whatever to be gained by raising the lock walls to such a height; all that is necessary is to keep the upper gates and forebay above the flood level. The submersion of the rest of the lock for a day or two, once in ten or twelve years perhaps—these extraordinary floods are of rare occurrence—is a matter of no importance. At such times navigation would probably be suspended for country boats, owing to the danger of crossing the rivers, as they might then be swept out to sea. If, however, they could cross, they would pass round the locks and enter the canal at any of the gaps left for the passage of the drainage to be hereafter described. The bank of the river, and in fact the whole country, would, during such extraordinary floods, be submerged many feet deep, and be formed into a great lake.

Canal embankments.

15. The canal embankments will be three feet above the flood waters of the streams intersected. The crest will be eight feet wide, and side slopes 2 and 3 to 1 on the canal and inundation sides respectively. The levels are all shown on the longitudinal section in Book 1. The banks of the northern end of Range III are shown to be above the level of the highest recorded cyclone wave, while the southern end is protected by the side embankments of the Suburnrekha River. Tow-paths on a lower level have been provided, which will be above ordinary high flood level in the canal, but will be liable to submersion in extraordinary floods—a matter of no importance, as towing can be equally well managed from the tops of the embankments.

Water-supply.

16. The canal will be supplied, as has already been stated, during the rainy season from the surface drainage of the country through inlet sluices, and during the dry months from the tidal rivers and creeks crossed by it. The loss of water in Range III has been shown in paragraph 11 above to be 18,666,640 cubic feet in 10 days, or 21 cubic feet per second. Supposing it were quadruple that amount, the canal could be supplied through one of the inlet vents with a velocity of 3½ feet per second. Numerous inlet sluices have been provided for drainage purposes: they are distributed at intervals along the canal; a supply is therefore ensured from one source or

another, probably from March, when the north-west storms begin, and certainly during the monsoon. No silt will be carried into the canal by this water, coming as it does from a perfectly flat country.

Method of supply to avoid silting.

17. The tidal ranges of the Midnapore Canal, and the first and second ranges of this canal already constructed, are supplied through the locks at the ends; the result has been an enormous deposit of silt. This has always formed the greatest objection to tidal canals, and has been an endless source of expense in maintenance. Mr. Vertannes now proposes to supply the canals in the dry season through inlet sluices, instead of through the locks, and, in order to reduce silting to a minimum, he would only allow the water to enter the canal through the sluices at the top of the tide, and from the surface. Until the experiment is actually tried, it is impossible to say what the result may be; but the proposal commends itself as a thoroughly practical solution of what has always been a difficult problem. The plans of these sluices will be found in sheets I and II of Book 2. The object of the double channel shown on sheet II is to allow of the sluices being used alternately, so that one may always be available while silt clearance is going on in the other. As the water will only be allowed to enter with a depth varying from 1 to 3 feet, the *length* of waterway must be calculated accordingly. Mr. Vertannes, in his report and statements accompanying it, enters very fully into the question, and shows by careful calculation what waterway it will be necessary to allow for each range. It is unnecessary to give this calculation here. In order to suit the varying conditions of tide levels, the sluices will be provided with grooves into which planks may be dropped, so that the water will only be admitted at the top of the tide. The supply sluices of Range III will be placed at the north end, in the Bagda River. Ranges IVA and IVB will be fed from the Panchpara River, which contains less silt than the Burrabullong. Range V will be supplied from the outlet sluices provided for drainage in the several creeks crossed by the canal. In order to prevent the entrance of water through the lock gates, 'porte-valets' will be introduced in the gate recesses, by which means the gates will be kept closed against the rising tides. The silt-laden water, which can enter the canal, will then be confined to what is required for the passage of boats only.

Depth of water in canal.

18. The average depth of water in the canal during the cold season will be 8 feet, and during the rest of the year 10 feet; the minimum depth during average spring tides has been calculated at 7 feet, but at the *lowest* spring tides the depth may *possibly* be reduced for three or four days in the year to 6½ feet in Range III or 6⅓ feet in Range V. It is not expected, however, that this will cause any inconvenience to traffic. The average width of the water surface will be 74 feet in the cold season and 80 feet during the rest of the year.

Drainage.

19. The question of intercepted drainage is one of great importance, and will be dealt with in detail. It must be remembered that the country through which the canal passes is very flat and generally subject to inundation, partly from the overflow of the rivers. A natural sand ridge, extending along the coast, prevents the escape of the inundation water except at the points where the rivers debouch into the sea.

Drainage intercepted in Range III, Doobda jheel.

20. In Range III the principal drainage intercepted is that which collects in the low tract traversed by the canal in miles 12 to 17, known as the Doobda jheel, into which flows the drainage of 114 square miles of country. The Executive Engineer reports that after heavy rain, the water in this jheel, which is 26 miles in extent, is raised to the level of 112·50, and as the ground level, according to the section, is about 109, the depth will be 3½ feet. At first sight it would appear that the whole of this water might be drawn off by cuts into the Baliaghye khal, and that the expense of constructing sluices in the canal bank might be thus avoided. The objections to this arrangement are that (1) the khal is much silted up, and that it would be necessary to incur considerable expense in clearing it out, while there is no certainty that it would not again deteriorate; (2) that a bridge now existing at Baliaghye would have to be pulled down and rebuilt, the waterway being insufficient; and (3) that the salt tidal water would be admitted into the jheel and destroy the crops. It will be necessary, therefore, to construct inlet and outlet sluices across the canal. Inspection of the map, sheet I, Book 1, shows that 14 square miles of the jheel will be finally drained through the Peechabunnee khal, and 12 square miles by the Baliaghye khal. It seems to me to be quite sufficient to provide sluiceway in the canal banks for the discharge of six inches of water off the 14 square miles of country in 24 hours. The Executive Engineer has allowed for the discharge of four inches only, but the Superintending Engineer has enlarged the sluice and provided

for the extra cost in the estimates. With a head of one foot and sectional area of 24 square feet, 18 vents will discharge 2,160 cubic feet per second, or nearly the required quantity. The requisite head can be obtained by lowering the water in the canal through the outlet sluices opposite, and by the valves in the locks and supply sluices. Only during *heavy* rain it will be necessary to lower the canal water in this manner, and usually the flow across the canal will be very quiet.

Drainage intercepted in Range III.

21. In the first seven miles of the canal two small khals are crossed; this intercepted drainage is provided for by a new cut shown on the plan, sheet I. But if the lock is built at Baintghur, and the tidal creek from Surpai towards Contai is canalized, as recommended in paragraph 6, this cut will not be required. A drainage sluice must, however, in that case be built at the mouth of the creek. Between the 7th and 12th miles of the canal the drainage intercepted is that due to the flow off of six square miles of country, which is now discharged by existing sluices in Government embankments. Three vents of five feet each have been provided for this, which should be sufficient. In the 31st mile of the canal similar sluiceway has been allowed for the drainage of six square miles in the Bhograi pergunnah, bordering on the Suburnrekha River.

Drainage intercepted in Range IVA, mile 0 to 9.

22. In Range IVA the country through which the canal passes to the 9th mile is protected on the east and west by natural sand ridges, and on the north and south by the Government embankments. The sluices provided for in this part of the canal have the same waterway as those now existing in the embankments, and have been found sufficient.

Drainage intercepted—Ranges IVA and IVB.

23. In Ranges IVA and IVB the canal passes through a flat country subject to inundation of great width, caused by the Panchpara River and the spill of the Suburnrekha. This inundation can only find vent by the rivers through the gaps in the line of sand-hills before mentioned: it might, therefore, be thought sufficient to raise the canal banks above the flood level, and to connect the rivers by back drains, by which the water would be drawn off the country to each side, and it might fairly be said that this arrangement could, in fact, do no more harm than the natural sand-hills have already done. It must, however, be borne in mind that, by excluding the portion of country between the canal and the sand-hills, and thus reducing the inundated area, the floods east of the canal would be raised, and a portion of the country be brought under the influence of the floods which has hitherto been free from them. This arrangement must therefore be discarded, and the water be passed across the canal freely by wide gaps left in the banks; at the same time catch-drains must be made, and the tidal creeks, where required, deepened so as to thoroug hlydrain the lands after the floods have subsided. The objection to this arrangement which first occurs to the mind is that, if flood waters are allowed to flow across the canal, it must inevitably silt up. Consideration of the following circumstances, however, shows that such need not be the case. *First,* the water will in all cases be quite clear. Covering, as it does, a large area of flat land, it must necessarily deposit its silt before it reaches the canal, and, as a matter of fact, tanks which have been constructed for years in the inundated tracts have not silted at all. *Second,* the canal will always be filled up to the level of the ground by the inlet sluices at the commencement of the rains, so that the water will flow across the canal without plunging into it, and eroding the slopes. *Third,* the length and area of waterway provided is so large that the water will be carried across the canal with a velocity of only 2½ feet per second. The Executive Engineer had designed masonry floors and sides to these gaps, but I consider such a provision quite unnecessary, and have directed that brick rubbish only be used, wherewith to cover the floor and slopes. No arrangement could possibly be more simple, and yet there is no reason why it should not be perfectly effective. There will, moreover, be this advantage, that if the waterway proves to be insufficient, as much more as may be required can be provided by the simple expedient of cutting away the banks and depositing the soil in long lines at right angles to the direction of the canal; while, on the other hand, if the waterway is found to be unnecessarily large, it may be contracted by partially filling in the gaps. The above remarks apply also to Range V.

24. It would swell this note to an inordinate length to enter into the whole of the detail of the passage of the flood water across the canal in Ranges IV and V. For these details I must refer to the Superintending and Executive Engineers' reports; the calculations made by Mr. Vertannes have been verified so far as data are available, and if anything, err on the side of safety. I will as briefly as possible summarize the results.

25. In Ranges IVA and IVB the *highest* local floods rise to 116·00 above datum, the

level of the country being 111·50; the depth of flood is therefore 4½ feet, and it covers about 60 square miles in 24 hours, which is equivalent to a flow of 90,000 cubic feet per second. To provide for the passage of this volume of water, we have flood escapes of 6,800 and 4,000 lineal feet in Ranges IVA and IVB respectively, besides the spaces between the terminal locks in the Panchpara and Burabullong rivers, which are 2,300 and 4,700 feet; thus the waterway aggregates 17,800 feet in length, and the mean depth being 2½ feet, the sectional area of waterway will be 44,500 square feet, sufficient to discharge 90,000 cubic feet with a velocity of about 2 feet per second. Ordinary local floods only rise to 113·00 above datum, that is, 3 feet lower than the highest local floods, and pass off in two or three days.

26. With reference to the discharge of extraordinary floods, which attain, on the rare occurrence of an extreme flood in the Suburnrekha, say every 8 or 10 years, a height of 118·00 above datum, or 2 feet higher than the highest local floods, it is to be remarked that this level can only be reached if an extraordinary flood in the Suburnrekha should come down on top of a high local flood. The time occupied in covering 60 square miles two feet deep is said, from enquiry, to be 12 hours; but only 6 are taken, which is indeed allowing a very large margin for safety. A discharge of 154,860 cubic feet per second has therefore to cross the canal, for which the waterway is, as before, 17,800 lineal feet by 5½ feet in depth ($\frac{118 + 116}{2}$ —111·50=5·5), or 97,900 square feet, which will discharge 154,860 cubic feet with a velocity of about 1½ foot per second. The velocity might of course be very much higher without doing any injury, and therefore the waterway provided is excessive. The discharge by the rivers is left out of account, as their channels will not be interfered with, and they will continue to act as heretofore.

27. In paragraphs 47 and 48 of his report, Mr. Vertannes enters into a calculation of the discharge of the rivers at the points where they are confined to their channels by the ridge of sand-hills before mentioned. He shows that the aggregate discharge may be 118,940 cubic feet per second less than that for which provision has been made at the canal crossing; but I attach no importance to this result, as it is based on an assumption, and Mr. Vertannes acknowledges that there are no data for ascertaining the velocity at the intersection by the sand-hills, and the effect of the tides is not known. So far as it goes, however, it is confirmatory of the statement above made, that the waterway allowed across the canal is excessive.

Drainage intercepted in Range V.

28. In Range No. V the principal drainages crossed are the Talpudda and the Kansbans. The index map in Book I of plans shows the area drained by the various streams. The surveys of the sand ridge along the coast and sections of the rivers are given in sheets 21 to 25. The drainages of Range V may be divided into two portions:—

1st.—That from the Burraballong River to the ridge between the Talpudda and Kansbans.

2nd.—That between this ridge and the Metai River.

The area of country inundated in this first portion is 30 square miles, of which 10 square miles are intercepted between the canal and the sand-hills. The depth of the inundation is 116—111·50 = 4½ feet, and local enquiry shows that from 24 to 36 hours are occupied in raising the water to the full height. The volume of water required to fill this area to a depth of 4½ feet in 24 hours is equivalent to a flow of 9 inches in that time from the whole surface of the catchment basin, which, as will be seen from the index map, is 180 square miles. This would yield a discharge of 43,000 cubic feet per second. Applying Colonel Dickens's formula, $D = 825M^{\frac{3}{4}}$, M being the area in square miles, the discharge would be 40,500 cubic feet per second, which is sufficiently close. The discharge is provided for by flood escapes aggregating 3,000 feet in length and 4½ feet in depth, and 300 square feet of sluice way, making in all 13,800 square feet. The velocity would therefore be 3 feet per second. In this calculation the retarding effect of this inundation is not taken into account, and it is improbable that a higher velocity than 2½ feet would ever be attained; the provision made for the passage of this drainage is therefore ample. The Superintending and Executive Engineers have adopted a different method of calculation, but the results arrived at are practically the same.

29. In the second portion of this range, from the ridge between the Talpudda and the Metai, the area inundated cannot be ascertained; but that it is very large may be seen from the map, sheet 5 of Book 1. The principal rivers crossed are the Kansbans and the Gummai; the area of their catchment basin is 400 square miles, which, by Colonel Dickens's formula, above quoted, would give a discharge of 73,000 cubic feet per second. The waterway provided by the Executive Engineer is 4,000 lineal feet of flood escape and 225 square feet of sluice way; and as the depth of inundation is 4½ feet, the total area will be 18,225 square feet, which if

the whole of the floods were to cross the canal, would require a velocity of 4 feet per second. Such a velocity is never likely to be attained, as neither the retarding effects of the inundation or the great area flooded has been taken into consideration, nor the fact that a large volume of water finds its way across the country into the Metai. It is improbable that even a velocity of 2½ feet per second would be reached. It would appear to be very desirable to connect the Gummai nulla with the Metai west of the canal, and thus to draw off some of the drainage water from the former river into the latter. The effect would be to relieve the Gummai floods, and at the same time to improve the Metai; the more water that can be thrown into the latter, the greater the certainty that it will keep open. It seems unnecessary to say anything more on the subject of the drainage intercepted; but I may here repeat that if it is found that sufficient waterway has not been allowed, it will be easy to remove a portion of the canal embankments, and thus afford more room for the passage of the floods.

Inlet sluices.

30. Inlet sluices have been provided in the banks, so as to admit water to fill the canal to the level of the ground before the freshes occur; at such times the outlet sluices will be shut down until the required level is reached. The position of these sluices is shown in the sections and plans in Book No. 1 of the drawings, and the calculations will be found in the Executive Engineer's report in detail. The number of openings in each range is as follows:—

Range.	Number of openings.	Size of openings.
III . . .	23	5
IVA . . .	14	5
IVB . . .	7	5
V . . .	30	5

Outlet sluices.

31. Outlet sluices, so-called, are required, partly for the regulation of the water in the canal, and partly as a source of supply for the admission of tidal waters in the dry season; the position of these works is also shown on the plans and sections. The number of openings provided in each range is as follows:—

Range.	Number of openings.	Size of openings.
III . . .	8	5
IVA . . .	8	5
IVB . . .	10	5
V . . .	21	5

The masonry designs.
Sluices.

32. The drawings of the masonry works will now be briefly noticed. The sluices designed for the canal are similar to those already in use all over the Hidgellee District. I have directed that the thickness of masonry in the floors be increased to two feet from out to out of wing walls, inclusive of six inches of concrete, as I consider the dimensions allowed in the drawings insufficient. Full description of the various sluices is given in the Executive Engineer's report, paragraphs 63 to 68.

Flood escapes.

33. As already stated, I have altogether altered the design for the flood escapes, and substituted brick rubbish flooring for the masonry and concrete proposed by the Executive Engineer, thus effecting a large saving in the estimates. The velocity will not exceed 2½ feet per second, and the canal will be filled up, through the sluices, to the ground level previous to the passage of flood-water across it. The brick rubbish will therefore be sufficient to preserve the soil from erosion. Immediately in front of the escape, the Executive Engineer proposes to excavate the canal one foot below the normal bed level, and thus to form a silt trap. I hardly think this precaution necessary, but as the cost will be trifling, it may as well be done.

Locks.

34. The lock drawings are shown in sheets 7 to 10 of Book II. The dimensions of the chambers are 150 x 20 feet. The upper gates and forebay will be raised in all cases over extraordinary flood and cyclone-wave levels; but the coping of the chamber walls may be kept to one foot over spring tide level. The last five locks have been accordingly reduced in height. The lower sills have been in all cases raised two feet, for reasons already given in paragraph 12; thus a considerable saving has been effected. The mean thickness of the chamber walls will be ·40 of the height; the necessity for such unusual thickness has been made apparent by the recent failure of several tidal locks. Water will be admitted through filling culverts running the whole length of the chamber walls; but the number of small outlets to the chamber shown on the plan will be reduced by half. They will also be made rectangular instead of circular. The gates are to be of

teak, sheathed in copper. The sills and quoins will be of artificial stone, which has been found to answer well in the existing locks of the tidal canal. The length of the channel between the lock and the river bank has been limited to 150 feet; its sides will be protected by dwarf walls which greatly facilitate the removal of silt which accumulates at the lock entrance more than anywhere else.

Protective works.

35. For protection against floods, the canal banks in Ranges III and IV have been raised above flood-level. This has also been done in Range V; but besides this, a small embankment is required on the right side of the Burrabullong River to connect the canal bank with the high ground. The details of this are shown in sheet No. 18 of Book 1 of plans. The waterway of the Burrabullong will not be interfered with, as the area now flooded does not exceed one square mile. The east side embankment of the canal will for 3 miles be raised above flood-level, so as to exclude the floods from the Burrabullong, which spill over below the canal crossing.

Intercepted communications.

36. The only communication of any importance intercepted by the canal is the Midnapore and Contai road, which is crossed in the 10th mile of Range III. I consider it unnecessary to construct a bridge at this place, but would provide a thoroughly efficient and good ferry-boat. The reasons against the bridge are, that it would cause immense inconvenience to the enormous traffic which is sure to arise on the canal, and that the road is hardly at all used for wheel traffic. The number of villages to the east of the canal is but small; wherever necessary, ferry-boats will be located.

Buildings.

37. In Ranges III and IV of the canal several inspection bungalows already exist in connection with the Government embankments. These can, though at some inconvenience, be utilized for inspection purposes and for the accommodation of the officers during the construction of the works. But in Range V there are no buildings of any sort; it is therefore necessary to construct a second class bungalow, which should be 'pucca,' as a thatched roof would suffer in such an exposed locality from the violent storms so common on the coast. The out-offices, as designed, have been altered and much reduced; 15 temporary shelter sheds have been provided, at a cost of Rs. 1,250 each, for the use of the subordinate establishments while the work is under construction. The sum of Rs. 15,000 has been included in the estimates for buildings for a permanent storegodown and office at Balasore, the head-quarters of the division; this will certainly be required, but the detailed plans and estimates have not been submitted.

Rates of works.

38. The rates have been most carefully worked out by Mr. Vertannes, and seem to me to be amply sufficient; the details will be found in Statement N. He proposes to burn the brick and lime required for the locks with coal, which he estimates will cost from 7 annas at the northern end of the canal to 13 annas at the southern end. It is hoped, however, that by the use of wood-fuel, which exists in large quantities in the jungles on the Metai and in other places, and also by the adoption of "Bull's kilns," the rates for bricks will be much reduced.

Lime.

39. Gooting or kunkur is found at intervals along the line in the tidal khals and nullas. All the mortar to be used in the locks will be ground in steam mills, for which provision has been made in the estimates.

Lock-gates.

40. The rates for lock-gates, culverts, valves, and gearing, &c., have been fixed from the actual cost of similar works on the Midnapore and Orissa locks.

Earthwork rates.

41. The earthwork rates have been determined for the different ranges with reference to the facilities for procuring labour and the hardness of the soil, average depths of cutting and lead. To the rates thus fixed have been added 10 per cent. for maintenance during construction and 5 per cent. for contingencies; the result is as follows:—

	R	
Range III	3·45	per 1,000 c.ft.
„ IVA	3·90	„ „ „
„ IVB	4·05	„ „ „
„ V	3·90	„ „ „
Average	3·82	

The average depths of cutting in the several ranges is as follows:—

Range III	8·83
„ IVA	11·31
„ IVB	13·22
„ V	10·38

The above rates seem to me to be sufficient, from the following considerations:—(1) The actual cost of the earthwork on the Tidal Canal and diversion at Gowkhally was R 2·5 and R 2·6 per 1,000 cubic feet, inclusive of all contingencies, and was mostly done by imported labour; (2) the earthwork of the great sea dyke, varying in height from 16 to 18 feet, and with a base of from 130 to 40 feet in width, cost R 2·6 per 1,000, excavation having been made from one side only; (3) the rate of earthwork for repairs is only R 2 per 1,000 at the present time; (4) labour will generally be plentiful, and work will be provided for the people almost at their doors. Mr. Vertannes states that the people engaged in manufacturing salt for the merchants at Balasore refused to take advances from them in the hopes of getting employment on the canal; (5) the percentage allowed for contingencies and maintenance during construction will suffice to cover the cost of hutting coolies, drainage of excavation while in progress, temporary cross dams, &c. Mr. Walker, in his letter dated the 16th December last, No. 544, recommended that the rates for earthwork should be—

For Range III . . . . = 4·29 per 1,000 c. ft.
„ „ IV . . . . = 4·29 „ „
„ „ V . . . . = 4·40 „ „
Average 4·33 per 1,000.

That is about 8 annas per 1,000 only higher than Mr. Vertannes's rates. Mr. Walker based his recommendation on the assumption that the Coast Canal traversed a country similar to that through which the Kendrapara Canal extension to the Jumboo passes. There is, however, no resemblance in any way; the one is well cultivated and inhabited, the other a jungly wilderness; the soil in the one is stiff and impervious to leakage, as has been fully tested by trial pits; in the other it is soft; there can therefore be no comparison. The work will be done by petty contractors, and the rates have been fixed accordingly.

Objections to canal on engineering grounds.

42. Several objections have been raised to the construction of this canal on engineering grounds, which will now be briefly noticed. It has been said—

1st.—That the soil is so soft that there will be difficulty in excavating the canal, and in maintaining it afterwards.

2nd.—That the cross-drainage will wash back the soil into the excavation, and that silt will be deposited.

3rd.—That cyclones will seriously damage the works.

4th.—That, owing to the bed being below the tide level, it will be difficult to execute the works, and that on this account the rates allowed are insufficient to cover the cost of contingencies.

With regard to the first objection, borings have been made at the sites of the principal masonry works and at intervals along the line of canal. The specimens are now before me, and show that the soil is hard. For most of the proposed locks ghooting lime will be procured from the adjoining khals and rivers, which sufficiently indicates the nature of the soil; and in the canal excavation the difficulties to be contended with will arise more from the hardness of the soil than from its sandy or soft nature. Pits, 10 to 15 feet deep, have been dug without meeting water; there will therefore be no leakage. With reference to the second objection, the liberal waterway allowed, which can be added to *ad libitum* by simply removing a part o the canal banks, will pass the drainage across the canal with a velocity not exceeding 2½ feet per second, which, as is well known, will not affect clay; moreover, the banks will be turfed, and the beds of the escapes will be covered with brick rubbish. That some silt will enter the canal from the supply sluices at the ends of the ranges during the dry season is inevitable, but I think the arrangements made to feed the canal from the surface water, and at the top of the tide when the current is slack, will reduce the silt deposit to a minimum. During the rest of the year the supply will come from the drainage of the country, and the water will pass into the canal almost free from silt. Specimens of the water have been collected, and show this to be the case, and if further proof is wanted, it will be found in the fact that tanks excavated many years ago and covered by the inundation have not silted or shown signs of deterioration. Referring now to the third objection, cyclones fortunately are of rare occurrence. It has been shown that a long line of natural sand-hills protects the country, and that the wave could only reach the canal through the mouths of the rivers. It is probable that as cyclones are usually accompanied by heavy rain, the country would be, at all events, partially submerged, and thus the damage likely to occur would be minimized. But we have experience to guide us in this matter; the cyclone-wave of 1874 having swept over the lock-gates of the second range of the canal, submerged the coping three feet, and traversed the canal from end to end. The whole damage done was repaired at a cost of R 248. The fourth objection is groundless, as the bed is above low water level of spring tides, and accumulated rain-water can be drained out by a temporary self-acting sluice or shoot fitted with a valve. There will be no leakage water.

Estimated cost.

43. The estimated cost of the works is as follows :—

		R
Preliminary expenses		10,000
Land		1,07,906
Regulators		44,810
River and torrent works		1,89,787
Navigation works		8,76,746
Buildings		39,250
Earthwork		14,02,611
Total works		26,71,110
Establishment at 25 per cent.		6,67,778
Tools and plant at 7 „		1,06,854
Total direct charges		34,45,742
Indirect Charges.	R	
Capitalization of abatement of land revenue	23,000	
Provision for pensions, 20 per cent. on establishment	1,33,535	1,56,555
Total		36,02,297

Mileage cost.

44. The mileage rate for works only will be R 28,799. and for the total, exclusive of indirect charges, R 37,150.

Provision for establishments.

45. The provision made for establishments, at 25 per cent. on cost of works, is, I believe, more than is actually necessary; 20 per cent. would have been sufficient, as fully one-half the cost is for simple earthwork, which requires but little supervision; but as it is certain that more men will, in the present state of the establishments, be sent to supervise than are actually necessary, I have left the figures as given by the Superintending Engineer.

Tools and plant.

46. In a work containing such a large percentage of simple earth digging—probably 60 per cent. including excavation of foundations—4 per cent. on the whole cost will be ample for tools and plant, including ferry-boats. The Executive Engineer states that the labourers will bring their own 'kudalies.'

Capitalization of abatement of land revenue.

47. The item capitalization of abatement of land revenue requires no remark; the figures have been obtained from the Civil authorities.

Provision for pensions.

48. The provision for pensions is in accordance with the last orders of the Government of India on the preparation of estimates for irrigation projects.

Interest on borrowed capital.

49. The Superintending Engineer, in paragraph 36 of his report, has added an item of R 2,41,201, interest at 7 per cent. on the cost of works establishments, and tools and plant; this has been arrived, at by supposing that it would take three years to complete the works. He has therefore taken 4½ per cent. for one-and-a-half years, or, in round numbers, 7 per cent. on the whole sum. I see no necessity for including this item in an estimate sent to the Government of India for sanction, as the charge will be entirely provincial, and will rest with the Government of Bengal to pay.

Cost of maintenance.

50. In discussing the scheme from a financial point of view, the first consideration is the cost of maintenance. Colonel Haig, in his note of the 15th February 1878, paragraphs 52-56, shows that the actual cost of maintenance of the Tidal Canal in Hidgellee from 1873 to 1878 was R 742 per mile; and from considerations of the conditions of the proposed canals as compared with the existing ones, he states that "it may be safely assumed that it will not exceed Rs. 800, and may perhaps be kept down to Rs. 600." The relative conditions are—(1) that the number of locks in the Hidgellee Canal is one in every seven miles, while in the proposed canal there will be one in every 12; (2) that the Hooghly and Huldee carry more silt than the southern rivers; (3) that in the proposed canals the water will be below the ground level, instead of, as in the Hidgellee Canal, some feet above it; (4) that during the rains the canal will be fed by the

surface drainage of the country, which will be free from silt; and (5) that during the dry season the water will be supplied, not through locks, but at the top of the tide through side sluices from the surface.

51. I feel confident, then, that maintenance will not cost over Rs. 500 per mile, and we may with safety state that it will not exceed Rs. 600. I may here mention that the proposal to supply water only at the top of the tide, and through side sluices, instead of through the locks, had not been contemplated by Colonel Haig at the time he wrote his note of the 18th February 1878.

Annual charge for interest and maintenance.

52. Now, taking the cost of maintenance at R 600 per mile as above, and the rate of interest at 4½ per cent. on cost of works, establishment, and tools and plant, the annual charges will be—

	Rs.
Maintenance of 93 miles of canal at R 600 per mile	55,800
Interest at 4½ per cent. on capital of R 34,45,742	1,55,058
Total .	2 10,858

Probable traffic.

53. I now proceed to consider the traffic which may be expected on the canal. This question has been very fully considered by Colonel Haig in his note of the 15th February, above quoted. He shows in paragraphs 22 and 23, from statements carefully compiled by Mr. Vertannes, that the total export and import trade of the ports of False Point, Chandbali, and Balasore, with its minor ports, for the average of four years 1873-74 to 1876-77, amounts to 65 lakhs of rupees, of which 52 lakhs, or five-sixths is with Calcutta, and that the imports are wholly from that place, as well as two-thirds of the exports. The proportion of the latter would have been greater but for the abnormally large export to the south in consequence of the famine in 1876-77. In paragraphs 24 and 25, Colonel Haig quotes from a report from the Collector of Balasore, and shows that the ports on the coast of Orissa are unsuited for the requirement of a great trade. The Dhamra and Balasore rivers can only be entered by vessels of small draft. False Point is said to be rapidly deteriorating, the steamers of the British India Steam Navigation Company being now compelled to anchor outside; Pooree is an open roadstead. Ordinary ocean-going vessels must therefore lie outside at all these places, and in such cases the risk and expense connected with loading is well known.

54. In paragraph 31 Colonel Haig says,—

Importance of canal in times of famine. Colonel Haig's views.

> "In this connection it may be well to advert to the importance of such a coast line of canal in times like those of the last two years when vast quantities of grain are set in motion. No sea route could supply the place of a canal. The Dhamra can only be entered by steamers of limited draft, and the number of these cannot be increased on an emergency, except at such an enormous expense as the Government only could bear. False Point is at a similar disadvantage, and Balasore worse off still. But were a canal in existence, thousands of boats would swarm to it from all parts of Bengal were the demand to arise, and such a traffic as famine only can create would be accommodated without any expense or interference on the part of Government, and with the sole effect of doubling or trebling the navigation tolls, as in Hidgellee last year."

Mr. Norman's views.

55. There can be no question of the correctness of this view of the matter. As a preventive against famine the canal is indispensable, and it is not too much to say that if it had been in existence in 1865-66, the grievous famine of that year could not have occurred. Mr. Norman, Collector of Balasore, writes in paragraph 13 of his letter No. 1369, of the 12th March 1878, as follows:—

> "It seems to me almost impossible to lay too much stress upon the importance of this canal in case of famine. The isolation of the province of Orissa during the famine of 1865-66, the immense difficulties that beset every attempt to throw grain into it, and the consequent paralyzation of private trade and appalling loss of human life are notorious. I believe that every intelligent person who is thoroughly acquainted with the facts must admit that, were another famine unhappily to occur now, the province of Orissa would find itself virtually in the same condition with regard to difficulty of access as in the great famine of 1865-66. This being so, a canal, which would bring every part of the province within easy reach of the great rice mart of Calcutta, would operate more efficiently both in mitigation of famine and in lessening the strain on imperial resources than any other measure which can be devised, except a railway, the cost of constructing which in Orissa would be so enormous that a railway at the present time seems quite out of the question."

56. Again, in paragraph 16, Mr. Norman says,—

> "My opinion on the subject of the proposed Coast Canal has now been fully expressed. I consider that it will confer vast benefits on the country; that it will be impossible to devise any other public works beneficial in a like degree except a railway; that admitting a railway to be impossible, the construction of a navigation canal connecting Orissa with the rest of the presidency is absolutely necessary as a protection against famine in the province; and that there is every reason to believe the project now under consideration is financially

sound, and will at least pay interest on the capital sunk, together with working expenses. Though myself fully convinced of the superiority in point of durability, efficiency, and economy of tidal canals in this part of the country over high level canals, yet I have forborne to touch on this question, as it can be discussed more adequately by the Engineer Officers of Government."

Comparative cost of carriage by existing routes and by canal.

57. The next question for consideration is the comparative cost of carriage by existing routes and by the proposed canal. Mr. Vertannes in his very carefully prepared report of the 19th June gives the following particulars:—

NAME OF STATION.	PRESENT RATES OF FREIGHT.				Probable rates by the proposed canal.	REMARKS.
	By land, *viâ* Midnapore.	By sloop, by sea.	By steamer and boat from Chandbali.	By steamer to False Point and thence by boat.		
	Per ton. R *a.* *p.*	Per ton. R *a.* *p.*	Per ton. R *a.* *p.*	Per ton. R *a.* *p.*	Per ton. R	
Jellasore . . .	13 8 0	......	......	......	3·50	
Balasore . . .	17 8 0	11 0 0	......	......	4·09	There is no steamer to Balasore; when there was, the rate was Rs. 15 per ton.
Chandbali . .	......	......	11 8 0	......	5·51	
Cuttack . . .	......	......	19 8 0	23 0 0	7·81	

"From the above table it will be seen that the traffic is paying at present for all stations, except for Chandbali, *three-times* as much as it will pay when the proposed canals are ready."

Present actual cost of carriage.

58. The following are some particulars of present charges:—

	R	*a.*	*p.*
I.—Calcutta to Cuttack viâ False Point—			
Shipping charges in Calcutta, per ton	2	8	0
Freight to False Point, per ton	15	0	0
Boating to Cuttack "	5	8	0
Total .	23	0	0
II.—Calcutta to Cuttack viâ Chandbali—			
Shipping charges in Calcutta	2	8	0
Freight, average	9	0	0
Boating to Cuttack	8	0	0
Total .	19	8	0
III.—Cuttack to Calcutta viâ False Point—			
Boating from Cuttack to False Point	5	8	0
Steamer freight	9	0	0
Landing charges	2	8	0
Total .	17	0	0
IV.—Chandbali to Calcutta for rice—			
Shipping charges at Chandbali	1	5	0
Freight, per bag, R0-4-9	4	0	0
Landing charges in Calcutta	2	8	0
Total .	7	13	0

With reference to the last, it is explained that the low rate of freight per bag was due to competition, the usual rate being eight annas.

Cost by proposed canal.

59. Now, with regard to the cost of carriage by canal, Mr. Vertannes has shown the estimated cost of the proposed canal as compared with the actuals on existing routes in Bengal as follows:—

	Estimated. Pies.	Actuals. Pies.
(1) Cost of carriage, exclusive of tolls, per ton mile	2·55	2·27
(2) Cost of carriage, inclusive of tolls, per ton mile	5·52	5·32
(3) Cost of conveyance of passengers, per head	1·64	1·28

The rate of toll proposed for the Coast Canal is one anna per 100 maunds per mile, the same as on the Midnapore Canal; but that is on the measured maundage of the boat, which, inclusive of the return journey of the empty boat, on which toll is also levied, is 2·56 time the actual weight of the cargo.

Probable passenger traffic.

60. Mr. Vertannes allows for the conveyance of 100,000 passengers per annum on the proposed canals. Mr. Norman, the Collector of Balasore, considers this much too low, and would double the number. On the Midnapore Canal in 1876-77, 137,000 passengers were carried over 48 miles of canal. Now, when we consider the vast number of travellers that flock to Cuttack and Pooree, and their known dislike to the sea, I think there is little doubt of the correctness of Mr. Norman's views, that 200,000 travellers will take the canal route. We shall be perfectly safe in calculating on 100,000.

Mr. Norman's estimate of conveying passengers by canal.

61. The following figures in decimals of a rupee, taken from Mr. Norman's report, show the estimated cost of conveying each passenger from Calcutta to the principal stations along the canal:—

	Suburnrekha.	Balasore.	Metai River.	Chandbali.	Patamundi.	Cuttack.
	R	R	R	R	R	R
Tollage	·275	·395	.582	·582	·582	·934
Cost of boat and crew . .	·398	·521	·703	·868	·959	1·19
Total cost of conveyance .	·673	·916	1·285	1·450	1·541	2·124

The Chandbali steamers carried in 1876-77 66,880 passengers, the price of a ticket being from R2-8 to R3-8, and on occasions of great demand R15 was given for a passage.

Statement of cost of carriage of goods and passengers by canal.

62. The following tables, abstracted from Statement W attached to Mr. Vertannes's report of 19th June 1877, show the estimated cost of transport to the different points along the coast and to Cuttack:—

Goods.

	DISTANCE FROM CALCUTTA.			COST PER TON.			Cost per ton mile.
	River.	Canal.	Total.	Boat charges.	Tolls.	Total.	
	Miles.	Miles.	Miles.	R	R	R	Pies.
Balasore	52½	81½	134	2·18	1·91	4·09	5·86
Chandbali	86	119	205	2·72	2·79	5·51	5·16
Patamundi	108	119	227	2·81	2·79	5·60	4·73
Cuttack	91	179	270	3·64	4·21	7·85	5·58

Passengers.

STATION.	DISTANCES FROM CALCUTTA.			Boat charges per head.	Tolls per head.	Total per head.	Total per head per mile.
	River.	Canal.	Total.				
	Miles.	Miles.	Miles.	R	R	R	Pies.
Balasore	52½	81½	134	·765	·395	1·16	1·66
Chandbali	86	119	205	1·12	·582	1·70	1·59
Patamundi	108	119	227	1·20	·582	1·78	1·50
Cuttack	91	179	270	1·44	·934	2·37	1·68

Probable returns.

63. The estimate of returns will be found in Statement D of Mr. Vertannes's report, which has been summarized as follows:—

Revenue from Goods Traffic.

	Goods traffic.	Proposed tolls per 100 maunds.	Revenue.
(1) Direct—	Mds.	Mds.	Rs.
Range III.—Russulpore to Suburnrekha . . .	25,24,000	2·61	65,876
Do. IV.—Suburnrekha to Balasore . . .	15,41,600	2·05	31,603
Do. V.—Balasore to the Metai . . .	8,60,600	3·26	28,056
Total direct revenue .	......	...	1,25,535

	Goods traffic.	Proposed tolls per 100 maunds.	Revenue.
(2) Indirect—	Mds.	Mds.	R
Range III	11,53,000	0·96	11,068
Do. IV	11,53,000	1·48	17,064
Do. V	2,16,000	3·67	7,912
Total indirect revenue	......	...	36,044
Total estimated revenue from goods	......	...	1,61,579

Revenue from Passengers.

	Number of Passengers.	Proposed tolls.	Revenue.
		R	R
(1) Direct—			
Range III	100,000	·168	16,795
Do. IV	95,000	·133	12,635
Do. V	85,000	·217	18,445
Total direct	......	...	47,875
(2) Indirect—			
Range III	100,000	·062	6,200
Do. IV	100,000	·096	9,595
Do. V	45,000	·277	12,465
Total indirect	......	...	28,260
Total passenger revenue	......	...	76,135

Additional goods traffic on Ranges I and II.

64. Colonel Haig has pointed out, in paragraph 49 of his note, that Mr. Vertannes has omitted from the anticipated traffic of Ranges I and II of the canal 9,34,000 maunds of goods which are sent by land from Balasore to Baliaghye, and he shows that this should be included in the traffic returns, which would add R22,600 to the receipts.

Probable revenue.

65. The revenue would then be as follows:—

	R	R
Goods revenue	1,61,579	
Ditto	22,600	
		1,84,179
Passenger revenue	......	76,135
Total	......	2,60,314

This is more than sufficient to cover the working expenses and interest on the cost,—*vide* paragraph 52.

Rice trade with Calcutta.

66. Mr. Vertannes, in preparing his Statement D, above summarized, has taken it for granted that the whole land and sea-borne traffic from Balasore to Calcutta, as well as all that by sea between Calcutta and Chandbali and False Point, will be carried on the canal, and in the calculation of probable returns he has added but little to what the traffic actually is at present. The principal item of trade is rice. The following tabular statement shows the quantities actually exported and the assumed probable traffic:—

YEAR.	QUANTITY OF RICE ACTUALLY EXPORTED TO CALCUTTA.				
	From False Point.	From Suburnrekha.	From Balasore.	From Chandbali.	Total.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
1873-74	......	15,460	260,355	233,508	509,323
1874-75	......	732	232,708	464,010	697,450
1875-76	20,709	10,403	141,415	190,285	362,812
1876-77	183,973	17,113	41,114	224,805	467,005
Total	204,682	43,708	675,592	1,112,608	2,036,590
Average	102,341	10,927	168,898	278,142	560,308
Assumed probable canal traffic	110,000	16,000	184,000	300,000	610,000

Considering the great area of country, the produce of which should find its way to False Point, the quantity allowed, 5,500 tons of rice, seems to be ridiculously small.

Other probable sources of income.

67. Mr. Vertannes takes no credit for Miscellaneous receipts, which the Collector of Midnapore thinks would be R12,000, *vide* paragraph 23 of his report; and if Mr. Norman's estimate of passenger traffic be correct, R75,000 more should be added to the receipts on that account. Mr. Harrison, Collector of Midnapore, in paragraphs 20 to 22 of his report of the 18th October, suggests the imposition of tolls on boats using the Huldee, Russulpore, and Metai, and other tidal estuaries and considers that such taxation would be perfectly justifiable. If this could be done, the increase to the income would be very great. Mr. Beadon, Collector of Cuttack, in his report No. 1088, of the 1st November, in paragraph 6, quite independently of Mr. Harrison, makes a similar suggestion as regards the tidal creeks in Orissa. The facilities of carriage given by the canal would probably drive the locally manufactured salt out of the field, and bring Liverpool salt into the market. This question is dealt with by Mr. Norman in a special report on the subject, No. 1369, of the 12th March 1878, which was called for by His Honor the Lieutenant-Governor. Mr. Norman gives calculations which show that the cost of each kind would be the same after the completion of the canal, and points out that as the Liverpool article is pure and white, and the locally made salt dirty, the former would be preferred. Here, then, is another probable source of income. Mr. Norman in his report also mentions that the tributary estate of Moyarbunge would probably yield supplies of slate, timber, and other produce which would be brought down for the Calcutta market when facilities for transport are afforded.

68. I think it may fairly be assumed that the stimulus given to trade by the immense reduction in cost of carriage and the opening up of the tidal creeks in Orissa, by which Pooree and Ganjam will be brought into direct communication with Calcutta, will largely increase the traffic, but no credit has been taken in calculating probable returns on this account. I feel very confident of the success of the project financially, and am satisfied no more promising scheme has ever been laid before the Government.

Opinion of Collectors of Midnapore and Balasore.

69. It will be seen from the reports that the Collectors of Midnapore and Balasore have expressed strong opinions in favour of the Coast Canal, and now I may quote from the former, paragraph 26:—

> "I would, however, urge that, even if there is a deficiency of R20,000 or R30,000 for the first four years, the indirect advantages to be gained ought not to be entirely overlooked. The Midnapore canal has permanently cheapened salt in the bazar by 15 per cent.; it has nndoubtedly added to the value of rice, though owing to the fluctuations in the grain, it is difficult to give the precise amount; it has added greatly to the value of jungle produce and timber; and, in short, I am collecting evidence which tends to show that it has raised the value of landed property within the area tapped by it to the extent of 25 to 200 per cent. It is certain that the land opened up by the canal is improving so rapidly in value that it sells at for 26 to 35 times the profits. Orissa is temporarily settled, and the facilities of trade which the canal must infallibly bring to at least some part of the country will tell upon the next assessment of land revenue."

Mr. Norman, Collector of Balasore, has expressed himself even more strongly in favour of the Coast Canal,—*vide* quotations *ante*, paragraphs 55 and 56.

Opinion of Collector of Cuttack.

70. Mr. Beadon, Collector of Cuttack, in his report No. 1088, dated 1st November, says but little on the subject, merely stating that he doubts whether the imports or exports of Orissa can ever justify the construction of the link line between the High Level Canal and Metai River. As this is not at present contemplated, nothing more need now be said about it. Mr. Beadon, however, strongly advocates the improvements of the tidal creeks along the coast, so as to open up the Pooree District.

Mr. Beames' (Officiating Commissioner of Cuttack) opinion.

71. It is necessary for me now to notice the report of Mr. Beames, the Commissioner of Cuttack, who is opposed to the construction of the Coast Canal, and to reply *seriatim* to his objections.

72. In paragraph 3 he states that "it requires no professional knowledge to see that a canal running across shifting sand, liquid mud, bottomless morasses, and tidal rivers, will be costly to execute, difficult to maintain, and liable to frequent interruptions." This statement has, I trust, been completely refuted by the facts mentioned in this report as to the nature of the country; and from personal knowledge of the ground, I can myself say that it is utterly devoid of foundation.

73. In paragraph 4, Mr. Beames quotes Mr. Ravenshaw, as follows:—

> "I believe the tidal canal will never provide satisfactory thorough communication free from serious interruptions. It follows the coast swamps, and avoids all the chief centres of trade, and will prove a very penny-wise-and-pound-foolish project."

But the fact is that the canal *does* pass through, or close to Baliaghye and Balasore, and will connect with Chandbali, and these are the principal marts and centres of trade.

74. In paragraph 5, Mr. Beames states that the leading merchants were unanimous in stating that the canal was not required, and would not be used for trade. He also gathers from an article which appeared in a local newspaper that the traders considered the canal unnecessary. This is not to be wondered at, when it is explained that these traders and the newspaper proprietors are owners of sloops!

75. How far the statements in paragraph 6 are correct may be judged from the report of the Collectors of Midnapore and Balasore, so often quoted in this report. Mr. Beames states that Commissioners, Collectors, Deputy Collectors, Superintending and Executive Engineers, native traders, and leading landholders "are unanimous in considering it (the canal) absolutely useless."

76. In paragraph 8 the Officiating Commissioner states that Mr. Vertannes "has with very great care, patience, and labour collected and arranged a mass of facts which prove distinctly the following points:—

"I.—That the trade of Orissa does not at present follow the direction to be taken by the proposed canal."

How could it do so? There is at present no road or other means of communication in that direction.

"II.—That, in order to yield a return which will pay the interest on 30 lakhs, it will be necessary that the canal shall absorb all the trade, both export and import, which at present passes through the ports on the Orissa coast.

"III.—That consequently the whole trade of the province must be diverted from its present channel."

It is to be regretted that Mr. Beames did not, apparently, read the headings of the statements which Mr. Vertannes "had with very great care, patience, and labour collected and arranged." If he had done so, he would have seen that that officer based his calculations on the trade with Calcutta only.—(*Vide* Statement Z attached to Mr. Vertannes's report of 19th June 1877.)

"IV.—That to effect this change the only inducement we can offer is the great saving in cost of carriage, *viz.* from R25 per ton, as at present, to R7-8 per ton by the proposed canal."

I should have thought this inducement quite sufficient to attract trade.

77. The figures given in paragraph 17 of Mr. Norman's report of 6th November 1877 completely refute the statement made by the Officiating Commissioner in his 13th paragraph. It is shown that for the last four years an average of 97½ per cent. of the total imports, and of 71 per cent. of the total exports, were in connection with Calcutta, and that the latter would have been much higher but for the famine in Madras in 1876-77, which drew off 54 per cent. to the south in that year.

78. I am unable to follow Mr. Beames in his argument in paragraph 16, that the loss to Government in the Customs Department from the export duty on rice must be set against the profits from the canal. The canal will not take produce to foreign ports; there cannot, therefore, be any loss in customs. It is more likely to increase them by facilitating transport to the ports from the producing districts.

79. In paragraph 17 the Officiating Commissioner says:—"As to passengers, I will only say that time is valuable to a certain extent even to natives, and that the much greater rapidity of the sea route would always make it a formidable competitor to the slow canal route." The whole distance from Calcutta to Cuttack is 270 miles by canal and river; this would be accomplished with ease by suitable canal steamers in 48 hours. I would invite a perusal of the 14th paragraph of Mr. Norman's report on this subject, but I cannot refrain from quoting part of it here. Alluding to the steamers plying between Calcutta and Chandbali, he says:—

"The steamers are exceedingly inconvenient and distasteful to natives. Both the Chandbali steamers arrive and depart on the same days, and passengers arriving at Chandbali from the interior have sometimes to wait almost a week for their steamer. Chandbali is during the rainy season a place exceedingly difficult of access by land, as the routes leading to it consist of tracks which become entirely submerged for long distances together and to considerable depths. In the steamers the passengers are packed together very much like sheep; the females, except first class passengers, have no secluded accommodation, and males and females alike are half-starved during the voyage, as caste prejudices prevent their eating cooked food on board. In spite of all these drawbacks, the Chandbali steamers during 1876-77 carried 66,880 passengers, and would have carried more, had their carrying capacity at times of religious festivals been greater. On such occasions, indeed, the temptations to overcrowding are very great, and overcrowding sometimes occurs. Masters have three times been convicted of it, and punished very heavily during the past three years. Under these circumstances, there can, I think, be no reason to doubt that were a canal made, the whole of the passenger traffic now carried by steamers would be transferred to it."

80. I have been thus particular in commenting on the statements made in the Officiating Commissioner's letter, because naturally great weight would otherwise be given to his remarks.

Mr. Vertannes, Executive Engineer.

81. It only remains for me now to mention the manner in which the plans, estimates, and reports have been prepared. I have quoted with confidence from the statements of trade and traffic so laboriously collected by Mr. Vertannes, and it is satisfactory to be able to state that the Collector of Balasore has testified to their correctness, and satisfied himself "of the care, diligence, and fidelity which have been bestowed on the compilation of his statements." Equally satisfactory is the care that has been taken in the preparation of the detailed drawings and estimates, and the collection and compilation of statistics connected with the drainage of the country, and the calculations of water-supply, &c. I think it must be acknowledged that no more carefully prepared project has ever been submitted for sanction of Government. The credit of this is entirely due to Mr. Vertannes. Colonel Haig was sanguine that the project would prove highly remunerative, and I have myself every confidence in its success, and trust the Government of India may be pleased to accord early sanction to the construction of the canal.

15th February 1879.

H. C. LEVINGE,
Chief Engineer.

From H. C. **Levinge**, Esq., Joint Secretary to the Government of Bengal, Public Works Department, Irrigation Branch, to Secretary to the Government of India, Public Works Department,—No. 1672I., dated 28th April 1879.

With reference to your No. 3721. of the 19th October last, and previous correspondence, I am directed to submit the detailed plans, estimates, and reports of the Orissa Coast Canal, together with a note by the Chief Engineer and a memorandum by the Secretary in the Financial Department of this Government.

2. The tidal canal is designed, in continuation of the existing Hidgellee Canal, to connect the Hooghly with the river and canal system of Orissa.

3. The length of this connecting link is 92¾ miles, divided into three ranges as follows:—

	Miles.
(1).—From the end of the present tidal canal to the Suburnrekha	31¼
(2).—From the Suburnrekha to the Burrabullong at Balasore	23½
(3).—From the Burrabullong to the Metai (a tidal river falling into the Brahmini at Dhamra)	38
Total . .	92¾

The total distance by this route between Calcutta and Cuttack is 270 miles, which can easily be traversed by steamer in 48 hours, the river and canal navigation being 91 and 179 miles respectively.

4. The proposed works consist of simple cuts between the tidal rivers with level beds and locks at the ends of each section. Ample provision has been made for drainage and for the passage of flood-waters across the canal, while a new arrangement of supply sluices of peculiar construction has been proposed for the admission of water in the dry season, by which it is confidently expected that the deposit of silt and consequent expense in maintenance will be much reduced.

5. The minimum depth of water in the canal will be 7 feet, and the surface width (with that depth) 71 feet; the locks will be 150 feet long and 20 feet wide; the canal will therefore be well suited for steam traffic.

6. The estimated cost of the canal is for works only R26,71,110, and with establishment and tools and plant R34,45,742. The usual book charges raise the amount to R38,43,498, inclusive of R2,41,201 interest at 7 per cent. during construction; this item was omitted by the Chief Engineer for reasons stated in paragraph 49 of his note, but it appears that it should have been included.

7. The returns calculated on the actual existing traffic are estimated by the Chief Engineer at R2,60,000, and by the Secretary in the Financial Department at R2,56,000, while the cost of maintenance and interest on capital amount to R2,10,000.

8. In refutation of the statement made by Mr. Beames, Officiating Commissioner of Cuttack, in his No. 114 of the 30th October 1877, which appears to have attracted the attention of the Government of India, I am desired to refer to paragraphs 71 to 80 of the Chief Engineer's note. The Commissioner's remarks had not been previously criticised, because the Lieutenant-Governor considered that on the face of them, they were so absurd, so manifestly exaggerated, and so ignorant and illogical, as not to be deserving of notice.

9. The tidal creeks and estuaries at the mouth of the Mahanuddy south of the Dhamra are now being opened up and improved, and it is expected that no difficulty will be experienced in connecting them with the Chilka Lake. Ganjam will thus be brought into communication through the Coast Canal with Calcutta.

10. The Lieutenant-Governer is of opinion that the High Level Canal should eventually be connected with the Coast Canal by a link from the Metai to Bhuddruck, and that the locks on this link should be of the full size (150 feet by 20 feet). Direct through communication with Cuttack would then be established for a class of boats which cannot traverse the branch canals to the coast, *viz.*, the Talduuda, the Kendrapara, and the Gobri, the locks on which are only 100 feet by 17 feet.

11. The province of Orissa is now the only one in Bengal which is completely isolated and cut off from all communication with Calcutta by rail or river, and thus trade is driven to take the sea route; but the ports are so inferior that transport is attended with many difficulties and consequent expense. False Point harbour is said to be rapidly deteriorating, and the steamers of the British India Steam Navigation Company are forced to lie outside, while the only other port of any importance, the Dhamra, is blocked by a bar, on which the depth at low water is only 9 feet: this port is therefore inaccessible to any vessels except those of limited draft. In the absence of a railway, which from the excessive cost attending the crossing of the enormous drainage intercepted is impossible, the Coast Canal is an absolute necessity. Since the famine of 1865-66 in Orissa, actually nothing has been done to improve the means of communication with the province; but were the Coast Canal once constructed and another famine unhappily to occur in Orissa, a vast number of boats from the rivers of Lower Bengal would be concentrated for the carriage of grain without any additional expense to Government, while the tolls would at the same time be greatly augmented. The importance of this canal, passing as it does through the centre of the most promising rice country in India, cannot, in the opinion of the Lieutenant-Governor, be overrated, and he considers that, even if there was no possibility of the interest on capital being repaid, it is a work which should be undertaken from the Famine Fund as a preventive measure.

12. I am to add that the project has the entire approval and confidence of the Lieutenant-Governor, and that he considers it should be taken in hand as soon as possible.

13. With the above strong recommendation of the Lieutenant-Governor, I am to ask sanction to the project at a total cost, exclusive of book charges, of R34,45,742.

Note by the Inspector General of Irrigation on the Orissa Coast Canal,—dated 20th October 1879.

The project has been drawn up evidently with great care, and the information on all, except one or two points, is very full and complete.

The estimates provide for a navigable canal connecting the existing "Tidal" Canal with the Metai, a navigable tidal stream joining the Brahmini River near Dhamra.

The entire distance between the Hooghly and the Metai is divided into six sections, thus—

	Miles.	
SECTION I.—Hooghly to Huldee	11	
" II.—Huldee to Russulpore	17	
		28 in operation.
" III.—Russulpore to Suburnrekha	31¼	
" IVA.—Suburnrekha to Panchpara	17	
" IVB.—Panchpara to Burrabullong	6½	
" V.—Burrabullong to Metai	38	
		92¾ now estimated for.
TOTAL		120¾

The canal is simply an open cutting connected by locks with the tidal rivers at each extremity of the several sections.

During the rainy season or wet weather, the canal will be supplied by the drainage water intercepted on the western bank; at other times by tide water.

The minimum depth of water to be retained in the canal generally is fixed at 7 feet, with reference to the draught of the largest country boats which is stated to be from 6¼ to 6½ feet.

As the drainage water always stands at a higher level than the tidal surface, the bed levels have been fixed with reference to the latter, at average high water of springs in the winter season, for all the sections except IV B, which is only 6½ miles in length, and where, consequently, the loss in depth in the intervals between the spring tides would necessitate lowering the bed more than is advisable. The bed of this section is therefore fixed with reference to level of average high water *neap* tides.

The loss in depth during the interval between two successive spring tides (taken at 10 days) is calculated from certain assumptions. Evaporation is taken at ⅕th inch per diem, as obtained by actual experiment at Burdwan, in the cold season. Leakage through locks and outlets is assumed at 4 cubic feet per second.

Loss by working locks is calculated on the assumption that they would be worked 40 times in the 24 hours.

As the soil is stated to be everywhere of stiff retentive nature, no loss by percolation is anticipated.

No allusion is made to any observations for loss on the existing tidal canal. It would be well to ascertain what the loss is there.

Eight locks are provided for, one at each extremity of the several sections, the lower sills projected 2 feet below the level of the lowest tide water. The Executive Engineer had projected them at 4 feet below, which has been reduced by the Chief Engineer to 2 feet for reasons given in the 13th paragraph of his note.

The bottom width of the first two sections is fixed at 50 feet, the minimum depth of water being 7 feet, the width of the water line will therefore be 71 feet, or 75½ at ordinary full supply. In the two central sections the bottom width is 46 feet, but the bed is lowered 1 foot more than is necessary to provide for possible deposits of silt from the floods of the Suburnrekha and Burrabullong, The width at the water line will therefore be 70 feet, or, at ordinary full supply, 76 feet in Section IV A, 79 feet in Section IVB.

This width, judging by experience elsewhere, should be sufficient for a large traffic. The Kendrapara Canal in its lower reaches has not a greater width at the water line than 65 to 75 feet; and though steamers have been running on it for some time at the rate of 5 miles an hour and upwards, the side slopes remain uninjured.

No tidal water will be admitted into the canal through the locks. The great difficulty in working a tidal canal is the quantity of silt deposited at each influx of the tide. Separate inlets, close to the terminal locks, have therefore been designed to admit only the surface water, the sills being laid 3 feet only below ordinary high water spring tides.

How far these will effect the desired purpose remains to be seen, but the arrangement promises well and bids fair to solve a confessedly difficult problem.

The tidal supply for Section III will be drawn, as above described, from inlets on the Bagda River; for Sections IV A and IVB from the Panchpara. Section IVB will also partially, and Section V altogether, be supplied through masonry inlets at various points along the canal bank, which will also serve as drainage outlets in the flood season.

The drainage water, which is to supply the canal during a portion of the year, will be admitted by masonry inlets at various points along the western bank.

The disposal of the flood waters or inundations intercepted by the canal on its western bank forms one of the main difficulties of this project. The question has been very thoroughly dealt with in the papers sent up. It would lengthen this note too much to enter into the detail. The quantity of water to be arranged for must in such cases be to a great extent a matter of estimate, but all the facts bearing on the question which could be collected seem to have been carefully collated for the calculations.

Local inundation water will, as mentioned above, be admitted into the canal by masonry inlets, the surplus being passed out by outlets on the opposite bank. For the passage of extraordinary floods across the canal, gaps will be left in the banks on both sides protected by masonry work and pitching.

To admit of this arrangement, the channel, as shown by the sections, is everywhere "within soil."

These gaps can be widened, if hereafter larger waterway is found necessary.

The velocity of current through the masonry inlets is calculated at 5 feet per second; through the outlets 7½ feet per second; and in the gaps, or flood escapes, 2½ to 3 feet per second.

As the soil is everywhere stiff, no injuries should result from velocities of current so low as these.

The height of the cyclone wave of 1874 is shown on the sections only at the north end of Range III on the Bagda River. Colonel Haig, in his note of 15th February 1878, states that the wave swept along 40 miles of the coast from a point about 10 miles north-east of Balasore to the Metai River. I have since enquired about this, and find that the wave, as far as it could be ascertained, did not rise above the level of extraordinary floods shown on the section on the other portions of the line.

The canal embankments are projected 3 feet above the level of highest known floods, and the upper gates and forebay at each of the terminal locks are also above flood level. In high floods the lock chambers will be submerged, but this will not affect the stability of the works, and, as the Chief Engineer shows in his 14th paragraph, it cannot affect the traffic for any length of time.

The greater portion of the canal, it will be seen from the plans, is protected from the impact of storm waves by the sand ridge running parallel to the coast line; the exposed portions are at the mouths of the rivers and part of Range V near its termination in the Metai.

Trial pits at intervals all along the line show that the soil is in general very stiff and retentive, and no springs are met with anywhere near the level of the bed; and sand only in one instance. The pits at the lock sites reached water only in three instances. The first was on the Suburnrekha, at the termination of Range III, where water was met with 2 feet above foundation level of lock chamber; the second was at the Panchpara, where the water was 4 feet below the same level; and thirdly at the Metai, where a weak spring appeared 6 feet above the same level. The down stream curtain walls are founded 5 feet below the chamber floors, but this being a narrow excavation, should be easily unwatered. In each of the lock estimates R5,000 to R6,000 is included for unwatering foundations.

This question will be found more fully discussed in the supplementary note by the Executive Engineer, dated 4th September 1879.

No bridges are estimated for. There are none on the existing tidal canal. As the traffic is said to be insignificant in general, and on the only road of importance, that between Midnapore and Contai, wheeled vehicles are seldom used, ferry boats will answer all purposes. Bridges, unless of an inconvenient height, are always a source of trouble on a navigable canal.

The estimate does not provide for ferries separately; the cost, it is said, is included in the provision for tools and plant.

The only permanent buildings provided for are store godown and offices at Balasore, and one inspection-house in Range V. Shelter required in other localities is, it is said, obtainable in existing Government bungalows, connected with the embankments.

The rates on which the estimate is based are approved by the Superintending and Chief Engineers, and in those for brickwork (of which the locks will be chiefly constructed) a saving is thought probable. The earth-work rates seem fair for the soil as described. Mr. Walker, one of the ablest and the most experienced of the Canal Engineers, considered that these rates should be about 8 annas per 1,000 cubic feet higher, judging from the works in progress on the extension of the Kendrapara Canal in Orissa; the circumstances of the localities and the soil, however, differ materially, all in favour of the Coast Canal, which Mr. Walker was not cognisant of when he made his estimate.

The abstract of the estimate is given in the 43rd paragraph of the Chief Engineer's Note. Under main heads of account it is as follows:—

	R	R
Direct outlay—		
Works	26,71,110	
Establishment	6,67,778	
Tools and Plant	1,06,854	
		34,45,742
Indirect—		
Capitalisation of land-revenue	23,000	
Pension and Leave Allowances	1,33,555	
Interest while under construction	2,41,201	
		3,97,756
GRAND TOTAL		38,43,498

The interest in above statement is calculated on the assumption that the work will take three years to complete. As this point is not especially adverted to in the reports, and no statement of probable yearly expenditure is submitted, I referred to the Chief Engineer and annex the statement he has sent me, which shew the probable time of execution to be four years; and the interest accruing during this period, R3,09,279, which raises the indirect charges from R3,97,756 to R4,65,834, and the grand total to R39,11,576.

If men and funds can be supplied as required, there is no reason why the work may not be completed within the specified time.

The total length being 93 miles, the cost per mile of direct outlay only is R37,050; including the indirect charges, R42,060. The estimate appears to be sufficient, considering the work to be done and the local circumstances. The only items about which there must necessarily be some uncertainty are the cost of bricks and of foundations of locks.

A few suggestions regarding the designs I have embodied in a separate note: the only two points of importance are the level of the bed of the first and last range and the level of lower sills of the locks.

The lowest supply in the canal in the above ranges is calculated at 7 feet at the periods of average spring tides, but this may be reduced at lowest spring tides to 6½ or 6¼ feet; and as the draft of some of the boats will be as much as 6¼ or 6½ feet, I think it will be well to increase the minimum depth to 8 feet throughout by lowering the bed 1 foot.

The Chief Engineer in his 18th paragraph says that the reduction below 7 feet in depth will occur only for three or four days in the year, and will not, he considers, cause any inconvenience to the traffic; but in a navigable line like this, where the traffic will certainly be very large, it is advisable to take every precaution against even a short temporary stoppage.

Again, I would lay the lower sills of the terminal locks at four feet below lowest tide water, as originally designed by the Executive Engineer.

The Chief Engineer in his 13th paragraph gives his reasons for preferring the level of two feet below lowest water. The temporary interruption to the traffic which he admits would, however, in my opinion, be a greater evil than the additional silt deposit which he fears.

The probable returns from the scheme have been very thoroughly discussed by both Revenue and Engineer Officers, and the results brought out by the separate and independent calculations agree in the main.

The rate of toll is assumed to be the same as that on the Midnapore Canal at present, *viz.*, one anna per 100 maunds per mile (or 3·24 pies per ton per mile); but taking into calculation the average weight of the boat on which toll is also charged, for both forward and return trips, the weight on which toll is chargeable is 1·39 times the weight of goods carried.

The Executive Engineer's investigations show that the whole of the imports and two-thirds of the exports at the ports of False Point, Chandbali, Balasore and its five minor ports are from and to Calcutta, and the whole of this traffic, it is assumed, will be diverted to the canal.

The number of passengers is estimated at 100,000 annually. Credit is also taken for the indirect return or increase of tollage revenue on the existing canal lines which the opening of the proposed canal would lead to.

The total probable income is detailed in paragraphs 63 and 64 of the Chief Engineer's note.

The abstract is as follows:—

This calculation is made on the length of the canal as first projected, *viz.*, 91 miles. The revised length is 92¼ miles.

	R	R
Direct—		
Goods . . .	1,25,535	
Passengers . .	47,875	
		1,73,410
Indirect—		
Goods . . .	58,644	
Passengers . .	28,260	
		86,904
GRAND TOTAL .		2,60,314

The Financial Department of the Bengal Government considers that all the imports and two-thirds of the exports of Balasore, and two-thirds of the imports and one-third of the exports of Cuttack, will pass through the canal from and to Calcutta. On this assumption the whole goods traffic, when fully developed, is expected to amount to 30,00,000 maunds annually, which adding in the weight of boats gives 41,70,000* maunds as the gross weight on which tollage would be leviable; the average distance of conveyance is taken at 60 miles, and the rate of toll the same as given by the Executive Engineer.

The return from passenger traffic at R81,400† is considered too low; R1,00,000 is entered on this account.

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* 30,00,000 × 1·39.

† This includes indirect as well as direct income, and the tolls on the Hunsooa and Gobri junction which is not yet in existence and not included in the present scheme. Excluding the latter, the amount is R76,135.

The total income is thus as follows:—

	R
Goods	1,56,375
Passengers	1,00,000
Total	2,56,375

This total apparently includes the indirect as well as the direct income, and does not differ much from the estimate of the Canal Engineers.

In neither of the above estimates is anything entered for miscellaneous revenue, which the Collector of Midnapore would set down at R10,000 to R12,000 annually, and in the calculations very little is added to the amount of the existing traffic. There can, I think, be little doubt of a large increase in traffic when the line is opened throughout from Calcutta to Cuttack.

The current charges are thus estimated by the Chief Engineer—

	R
Maintenance of 93 miles at R600 per mile	55,800
Interest at 4½ per cent. on cash outlay R34,45,742	1,55,058
Total	2,10,858

The actual cost of maintenance on the existing tidal canal from 1873 to 1878 was R742 per mile. Colonel Haig considered that R800 per mile might safely be assumed as a maximum, but that it might possibly be reduced to R600. The Chief Engineer assumes the latter figure as a maximum for the reasons given in his 50th paragraph, and I have little doubt he is in the main correct. In the item of silt clearance alone, there must be a considerable difference.

The net profit, taking the income at the estimate of the Bengal Financial Department, and deducting all charges, will thus be R45,517, or R26,917 if the maintenance be assumed at the higher rate of R800 per mile.

This result, it is true, is partly dependent on the returns from increase of traffic on existing lines. It may be said that the scheme should be treated as an entirely separate concern, and the probable financial result estimated accordingly; but seeing how closely the completion of this link in the communication with Calcutta is connected with the future of the Orissa Canals, the probable effects on them must, I think, be considered in discussing whether the outlay on this link is justifiable.

The idea of a coast canal in this locality is not a new one. The original Orissa Project provided for two lines of navigable canal from Bhuddruck, near which the high level channel from Cuttack now terminates; one a high level *viâ* Balasore to the Midnapore Canal, the other to join the Metai River not far from the terminus of Range V of the scheme now submitted, whence it was to be carried parallel to the coast as a tidal channel to meet the Hooghly. The first two reaches of this now form the "Hidgellee Tidal Canal."

See Colonel Rundall's note, dated 20th November 1869—Proceedings March 1871, Nos. 1 to 14.

The reasons assigned for the double line were—first, because the coast line running on the lowest level, and requiring no large drainage works, as well from the softer nature of the soil, could be more quickly and economically constructed; and secondly, because on a great line of traffic, such as this is sure to become, it is most desirable that there should be always an alternative line, so that in the event of any accident happening to the one, the traffic may yet proceed without intermission along the other. Deficiency of the supply of water at Bhuddruck during the hot months was even then apprehended, and is given as an additional argument for the coast line, which being fed by the tides would have a sufficient supply at all seasons.

I need not recapitulate all the arguments for the completion of a navigable communication from Orissa to Hooghly, free from the drawbacks of the sea route. Even False Point, the only port worthy of the designation, is, it is stated, fast silting up, and the difficulties in loading and unloading sea-going vessels any where on that coast add very considerably to the freight charges.

There seems to be little likelihood of Orissa being connected with Calcutta by railway for many years to come, if ever, so that if the canal be not made, the province must remain nearly in the same state of isolation from the rest of the country as it was in the famine of 1865-66.

The only question seems to be whether the canal should be made on the high level route or on the low level as now projected.

	Mr. Walker.	Mr. Vertannes.
Direct outlay—	R	R
Works . . .	20,97,000	43,55,909
Establishment .	5,24,250	10,88,977
Tools and Plant .	1,25,820	2,61,354
Total .	27,47,070	57,06,240
Indirect—		
Interest . .	3,02,178	7,93,760
Pensions . .	1,06,062	
Total .	4,08,240	7,93,760
GRAND TOTAL .	31,55,310	65,00,000

Colonel Haig, in his note dated 5th October 1877, gives calculations which show that the cost of the former on the most moderate estimate must be prohibitive.

The returns from irrigation according to his estimate would hardly pay for the cost of distribution of the water, leaving no margin to cover the interest on the cost of the main channel.

The high level would have very little local traffic between Balasore and the Midnapore Canal. South of Balasore it would be a better alignment for local traffic than a low coast line; but if the canal is to be the main line of traffic between Calcutta and the province of Orissa, it should communicate directly with the estuaries of the Orissa rivers. If the traffic has to go *viâ* Cuttack and down the Kendrapara Canal, the sea route would always have advantage over the canal line.

Colonel Haig's opinion was formed after careful investigation and long consideration of the arguments for and against the two routes. At one time, as appears from his note dated 29th May 1873, he was strongly in favour of the high level line, fearing that according to the information at that time available, the inundation along the coast line would prove an insurmountable obstacle to a really reliable navigation.

Mr. Walker, the Superintending Engineer of the Orissa Canals, still holds to his view of the superiority of the high level line, mainly on the grounds of the advantages to the country of the irrigation from it.

The Committee who reported on the Orissa works at the close of last year, with reference to protective measures against famine, recommended the high level line between Bhuddruck and Balasore in preference to the coast line, mainly with reference to the irrigating capacity of the former, if it could be constructed at a less cost than Mr. Walker estimated, *viz.*, R31,55,310.

Including indirect charges.

They also suggested alterations in the designs which it was considered would materially reduce the cost.

The chief alterations recommended were, increasing the slope of bed and passing a large proportion of the drainage water through instead of under the canals.

The impossibility of carrying out these suggestions is clearly demonstrated by the Chief Engineer in his note dated 8th May last; as to the cost, there is little doubt that the high level would cost more—probably considerably more—than Mr. Walker's estimate.

From Balasore upwards the Committee appear to have been in favour of the coast line of communication with the Hooghly.

The strongest argument, in my opinion, against the high level from Bhuddruck to Balasore is the deficiency of the supply of water for it during the hot months, just the season when the canal would be most in demand in case of famine. It is shown that about 175 cubic feet per second is required for the proposed junction line from Bhuddruck to the Metai, 17½ miles long, and that the available supply *at present* falls occasionally for two months at a time below this, while the distance to Balasore is 50 miles, and there is no certainty that every drop of water which reaches Bhuddruck may not in cases of drought be required for irrigation in that locality.

As a part of the communication with the estuaries of the Orissa rivers, which it is shewn can be continued at a small expenditure to Pooree and Ganjam, and possibly hereafter to the Godavery, the coast line has decidedly the advantage, besides the freedom from weeds which are a source of much trouble and expense on the high level lines.

The main argument for the latter is that it will afford irrigation, but this may be provided if it be deemed advisable hereafter by damming the Salundi and the Suburnrekha rivers as proposed in the original scheme, and the canals for this purpose would cost much less than if navigation were also provided for.

The navigable link to connect the existing High Level Canal at Bhuddruck with the Coast Canal or with tide water in the Metai River, which the Bengal Government considers will eventually be required, involves the construction of the weir across the Salundi, whence irrigating channels could be led as proposed by the Committee above referred to.

The cost of completing the existing high level to the Salundi, and the canal thence to the Metai, is estimated by Mr. Walker at R12,19,750, two-fifths of which is for completion of the existing canal and the Salindee weir.

	R
Works	9,51,800
Tools and Plant	30,000
Establishment	2,37,950
	12,19,750

Into the question of the comparative advantages of the several routes to Cuttack, I need not enter here. The project now submitted should, I think, be dealt with independently; the other questions will come up for decision in connection with further development of the Orissa Canal scheme.

Sanction to the project is apparently asked for as a productive public work, though this is not expressly stated. The report of the Financial Department shows that the provincial revenues can easily afford the payment of interest on the proposed outlay. Without, however, an increase to the Productive Public Works grant, there is little prospect of funds being available for a long time, perhaps years, to come.

From the supplementary statement it will be seen that the Canal Engineers expect the full estimated returns in three or four years after the opening of the canal. If, as the Bengal Government anticipates, the whole of the traffic now taking the sea route to and from Calcutta is diverted to the canals, there is no reason why the change should not be effected in three or four years.

The difference in the cost of carriage alone must turn the scale in favour of the canal.

Since the receipt of this project, copies of correspondence[*] with the Government of Madras, regarding the continuation of the route from Ganjam to the Godavery, have been sent up by Bengal, with the suggestion that a thorough examination be made of the localities along the route indicated. Funds for the scheme, however, as Madras observes, are not likely to be available for some years to come.

[*] No. 3380I., dated 29th August 1879, with enclosures, from Bengal.

A copy is appended of a report[†] on the Buckingham Canal in Madras, which was considerably damaged in November 1856 by a cyclone wave and drainage from inland. The Executive Engineer, Mr. Vertannes, was deputed to examine the line with reference to remarks by Colonel Sankey on the risks a coast canal was exposed to. The report shows that the circumstances of the localities and the works are so very different in the two cases, that a comparison can hardly be instituted between them. Precautions have been taken in designing the project now submitted which seem to have been omitted in the Madras works; and the line of sand hills parallel to the coast must undoubtedly prove a material safeguard to the greater portion of the line in case of a cyclone.

[†] Dated 20th December 1878.

J. CROFTON.

Note by the Secretary, Public Works Department, on the East Coast Canal, Orissa,—dated 23rd January 1880.

I know of no more important project than this of opening out communication with Orissa, and thus giving practical effect to the improvements which the lessons of the Orissa famine taught us to be necessary.

The figures of the Bengal Government as to the probable income may be accepted, I think, for the Customs report on which the Bengal Government remark, as noted on the margin, shows that the development of trade is steady in its increase, and that the figures for 1878-79, which was a normal year, were much larger than the figures of 1876-77, which was considered a previous normal year, the intermediate years having been exceptional in consequence of the famine in Southern India.

Resolution on the Administration Report of the Customs Department, Bengal, paragraph 24, of 5th November 1879.

"With improved communications between the interior and the seaboard, further steady development may be confidently expected." This development consisted of an increase in the sea-borne trade from R7,84,135 in 1872-73 to R1,37,66,124 in 1878-79.

It is noted by Mr. Barbour that—

> "At the same time it cannot be overlooked that the existence of famine, or severe scarcity, in Southern India would, for the time, interfere materially with the ordinary course of trade.

But this seems to me an argument for extending the canal to Vizagapatam or even the Godavery, rather than against the making of it at all. The facility of export and import both north and south will be of infinite value as a protection against famine, whether in Bengal, Orissa or Madras.

The Government of Bengal remarks in the 9th paragraph of its letter that—

"the tidal creeks and estuaries at the mouth of the Mahanuddy, south of the Dhamra, are now being opened up and improved, and it is expected that no difficulty will be experienced in connecting them with the Chilka Lake. Ganjam will thus be brought into communication through the coast canal with Calcutta."

While Mr. Thomas (C. S.) of Vizagapatam, in writing on the urgency and facility of forming a port at Vizagapatam, says that the line northwards is—

"so level that from Chilka to Vizagapatam more than two locks would probably not be necessary."

It seems to me, therefore, that this Orissa Coast Canal will be the first section complete, and paying in itself of a line of water communication with Madras of the highest importance.

I cannot see that this project need be mixed up with the railway question. It will take a great many years to make a railway from Sumbulpur to Calcutta, if such a project can ever be considered. What seems more likely is a railway from Raipur or Sumbulpur to Vizagapatam, and its extension northwards to Benares or Gya through the coal-fields of Sirgujah or Palamow, and I think with this in view we should at once take up the question of Vizagapatam as a port.

The want of railway communication in the Central Provinces and the eastern part of Central (geographically speaking) India, where there is no market or no outlet except by the railway now being extended from Nagpur towards Raipur or Sumbulpur, is strongly put forward by Mr. Thomas, and I think, commercially speaking, the Government could not do better than to foster any projects having for their objects—

(i) bringing into communication by water Cuttack with Calcutta;
(ii) bringing into communication by water Cuttack with the Godavery and Madras;
(iii) the improvement of the Port of Vizagapatam;
(iv) bringing that port into communication by railway with the Central Provinces.

If the Government approved of this view of the case, ii, iii, iv might be separately considered, and the project now submitted might be forwarded to the Secretary of State for sanction, so that it may be taken up when money is available. For this purpose the proposal might go to the Financial Department.

I would not adopt the deepening of the canal by one foot proposed by General Crofton which will add a considerable extra cost. The boat traffic of the canal would soon adapt itself to the depth allowed.

The prospect of the opening out or deterioration of False Point harbour has an important bearing on this project, and the case should, I think, for this reason, be considered by Government in the Home Department also, before it is referred to the Financial Department.

ALEX. FRASER.

From the Government of India, to the Secretary of State for India, No. 264F. and C., dated 17th August 1880.

We have the honor to forward for consideration a project, styled the "Orissa Coast Canal" project, for completing the water communication between Calcutta and the canals and rivers of Orissa.

2. The estimated cost of the work is, directly, R34,45,742; and, including indirect charges and interest during construction, R38,43,498.

3. There appears to be no doubt that the revenue which may be reasonably anticipated will yield a fair return upon the outlay, and, on this ground alone, we should recommend theproject for the sanction of Her Majesty's Government.

4. But the necessity for opening out communications with the province of Orissa has so long been apparent that we should urge the prosecution of the most promising scheme available, even if the financial aspect were not so directly encouraging as in that of the present project.

5. The improvement of the harbour at False Point which is referred to in the papers is under consideration.

6. With these remarks we have the honor to recommend that the sanction of Her Majesty's Government be accorded to the estimates, amounting to R34,45,742, exclusive of book charges, debitable to grant No. 38, Productive Public Works.

Schedule of Papers.

1.—Letter No. 1672I., dated 28th April 1879, from the Government of Bengal, and enclosure, excluding detailed plans.

2.—Letter No. 3195I., dated 18th August 1879, from the Government of Bengal, and enclosures.

3.—Note by Major-General Crofton, R. E., Inspector General of Irrigation, dated 20th October 1879.

4.—Note by Major-General A. Fraser, C.B., R.E., Secretary to the Government of India, in the Public Works Department.

From the Secretary of State for India, to the Government of India, No. 47 P. W., dated 30th November 1880.

I have had under my consideration in Council your Excellency's letter in the Department of Finance and Commerce, No. 264, dated the 17th August last.

2. In this letter you request the sanction of Her Majesty's Government to the construction of a coast canal to complete the water communication between Calcutta and the rivers of Orissa. The direct cost of the work is estimated at R34,45,752, and the indirect charges and interest during construction at R3,97,756, making a total estimated cost of R38,43,498. You state that there appears, from the estimates submitted to your Government, to be no doubt that the revenue which may be reasonably anticipated will yield a fair return upon this outlay, and on this ground alone you recommend the project for sanction, adding, at the same time, that the necessity for opening out communications with the province of Orissa has so long been apparent that, even if the financial aspect of the project were not so directly encouraging, you would urge the prosecution of the most promising scheme available.

3. I entirely agree with your Excellency as to the general importance of affording means of communication between Bengal and the province of Orissa, and, after careful consideration of the scheme now submitted to me, and as it appears that the return from the work will be sufficient to cover the charge for interest, I sanction the prosecution of the work at an estimated direct cost of R34,45,742, such sum to be chargeable to the funds annually set apart for productive public works, on the conditions laid down in my predecessor's Financial Despatches, Nos. 105, dated 27th March, and 444, dated 13th November 1879.

From the Government of India, P. W. Department, to Secretary to the Government of Bengal, P. W. Department, Irrigation Branch, No.—25I., dated 19th January 1881.

With reference to your letter No. 1672I., dated 28th April last, I am directed to forward for your information a Despatch from the Secretary of State, granting sanction* to the construction of the Orissa Coast Canal at an estimated cost of R38,43,498, including indirect charges.

* Register No. 111. of 1880-81.

2. The plans and estimates forwarded with your above-quoted letter are herewith returned. I am also directed to forward for consideration a memorandum on the works and designs by the Inspector General of Irrigation.

3. Although the work has been sanctioned, there is no prospect of funds being available from the present productive public works grant for at least three years. It would not seem advisable to commence the work at all unless funds can be obtained to push the work energetically to a conclusion.

4. If the Government of Bengal can provide the necessary funds for this project from its own provincial resources, the work may be transferred from the category of Productive Public Works to that of ordinary "Irrigation and Navigation Works."

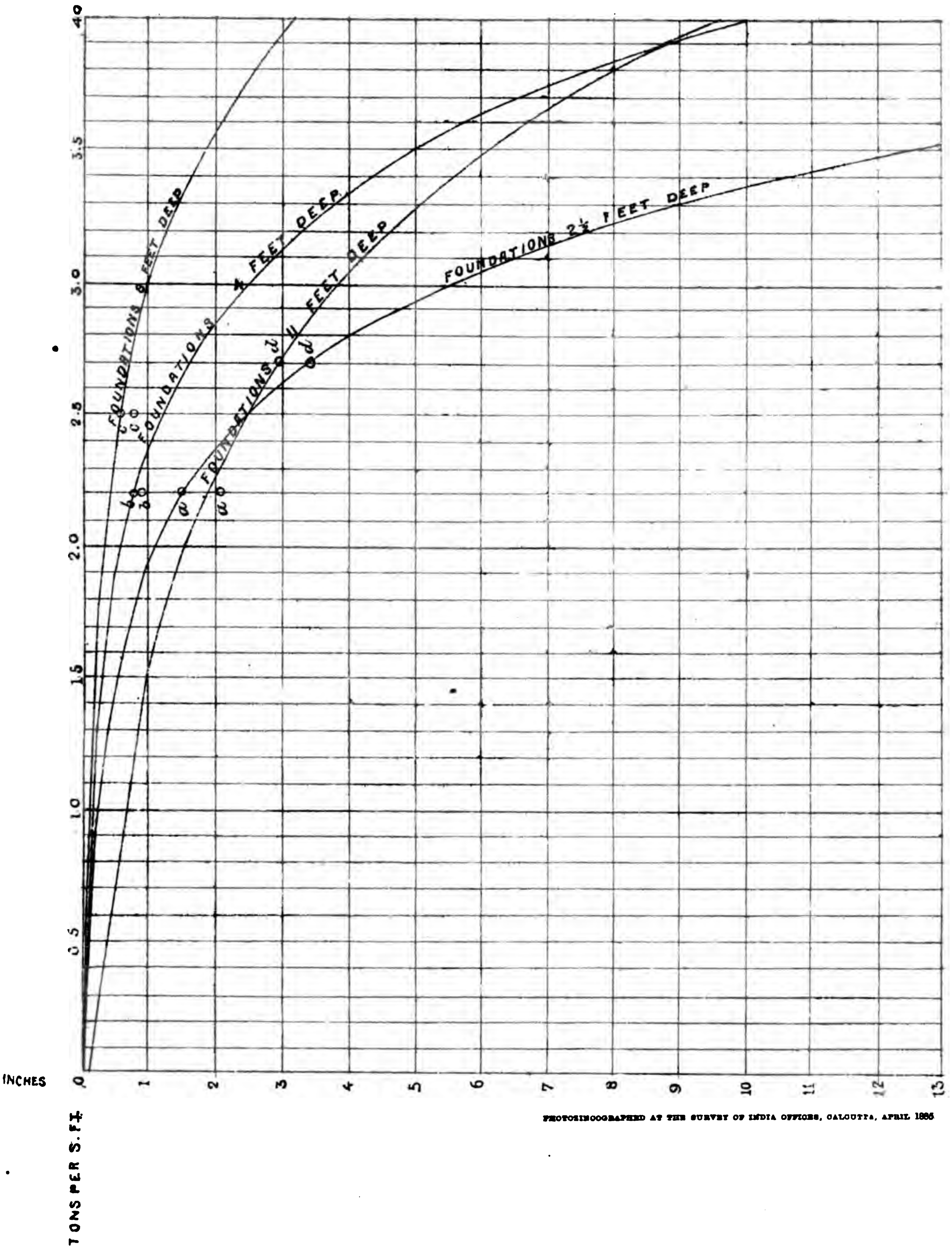
Note by MR. J. H. APJOHN, *Executive Engineer, Circular and Eastern Canals Division, on the subject of equalizing pressure on foundations.*

All locks hitherto built on the tidal rivers of Lower Bengal have cracked more or less; it is therefore proposed to examine in the following note the causes of these cracks, and the possibility of building a lock in such a way as to prevent them from occurring.

2. The soil in every case on which they have been founded is the well-known bluish black slimy clay with trunks of trees distributed through it, and in some cases vegetable remains, bearing a strong resemblance to peat such as is found in an Irish bog. This soil, as far as the writer is aware, is found within tidal range throughout the Gangetic Delta, and beginning about 10 feet below the surface soil goes to an unknown depth; the only instance in which it seems to have been got through is at Dhappa, where at a depth of 29 feet below mean sea, and 39 feet from the natural surface of the ground, a stiffer stratum was reached by the foundation wells of the lock, which stratum was described as very stiff clay with nodular limestone scattered through it.

3. The black soil in question is of a very treacherous nature, hard and stiff when dry, and in that state cracking much through contraction, and on the other hand, slimy and sub-

Fig. 1



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ject to slips and upheavals when a pit is sunk in it in its natural moist state. All buildings founded on it without the precaution being taken to have equipressure all over the bearing surface of the foundations have cracked badly, evidently the result of unequal settlement.

4. In order to arrive at some definite knowledge as to the safe weight to allow on foundations in the alluvial soil of Bengal, a series of experiments on a large scale was carried out in 1873 at the Akra Government Brick-field, and a note on them was published by Mr. Leonard, Chief Engineer, on the 17th May 1873. An analysis of the records of these experiments now made by the writer has resulted in the detection of an apparent law of settlement, *viz.*, that, as the pressure increases in an arithmetical series, the settlement increases in a geometrical.

5. The experiments were conducted by building brick-work piers founded at four different depths, *viz.* 2½, 4, 8, and 11 feet from the surface. These piers were 3' 2½" square, thus giving a bearing surface of 10·24 square feet. They were then loaded, so as to produce a pressure per square foot of bearing surface varying from 1·5 to 3·7 tons, the sinkage produced by the weights being accurately observed. Each pillar was loadedwith three different weights, increasing by a ton per square foot, and they were left with the weight bearing on them in each case until no further sinkage could be observed.

6. In Mr. Leonard's note the results of the experiments are not given in a form that conveys much information at first inspection, so the writer has put them into table No. 1. In it the pressures are shown (in the first column) increasing by tenths from 0 to 4 tons per square foot, and the sinkages observed are shown in inches and decimals in columns 2, 5, 8, and 11. It is at once seen that the sinkage increases more rapidly than the pressure. To try if the sinkage complies with the conditions of a geometric series, take the sinkage observed at (for the foundation 2½ feet deep) 1·2 tons per square foot pressure for the first term of a series of 21 terms and the sinkage observed at 3·2 tons for the last, the ratio will be found to be 1·17. With this ratio the whole series between 0 and 4 tons per squre foot is calculated, and it will be seen that the observed middle term agrees with the next term but one as calculated. In the same way, if series be calculated for the sinkages observed at the depths 4, 8, and 11 feet, it will be found that the ratios are respectively 1·15, 1·12, and 1·10, and that in two of the series the calculated differs from the observed middle term by only one place and in the last by one and-a-half places. It may fairly be taken as proved that, as above stated, the sinkages increase geometrically as the pressure increases arithmetically.

7. It is not stated in Mr. Leonard's note what was the nature of the soil found at the various depths at which the pillars were built, so to determine this important point, the writer has, with the assistance of Mr. Nightingale, Executive Engineer, 1st Calcutta Division, searched for and found the experimental pillars at Akra, and had a pit sunk in the midst of them, with the result that all the pillars, except that sunk to 11 feet, are discovered to be founded in light-coloured loamy brick earth, but the latter pillar is built on the black soil, which is reached at a depth from the surface of a little under 11 feet.

8. From the table the curves shown in figure No. 1 have been plotted, showing the relation between the pressure and sinkage at the different depths; these curves are evidently hyperbolas. The middle sinkage as actually measured is plotted and referred to the corresponding place in the curve by reference letters. It will be seen that for the depths of 4 and 8 feet these points fall almost exactly on the curves, and that for 2½ and 11 feet they are not so far, but that an almost similar curve to that plotted from the calculated sinkages could be drawn through the three points actually determined.

9. It will be noticed that the deeper the foundations the smaller the ratio of the series by which the sinkage increases, and these ratios themselves apparently conform to a law, *viz.*, that as the depth of the foundations from the surface increases in arithmetical progression, the ratios of the series expressing the rate of sinkage at each depth decreases according to a geometrical series, the ratio of which is less than unity. It will be found on trial that a series of 18 terms, of which the first term is 1·17 and the last is 1·10, will have a ratio of 0·99665, and that its 4th and 12th terms will be 1·15 and 1·12 as actually determined for the depths 4 feet and 8 feet from the surface, which are the 4th and 12th terms in an arithmetical series increasing by common difference of 0·5 from 2·5 to 11·0.

10. The conclusions that the writer would draw from the above analysis of Mr. Leonard's experiments are as follows :—

1st.—The initial sinkage for a pressure of, say, one ton to the square foot will depend on the nature of the soil, being greater for the black subsoil than for the surface loam.

2nd.—The ratio of the series by which the sinkage increases diminishes with the depth, the curve expressing it tends to become flatter indefinitely as the depth increases, but being a hyperbola never becomes absolutely a right line. The ratio of the series by which the ratios of sinkage at the various depths diminish is probably a function of the thickness of the alluvial crust, but at present there is not sufficient experimental data to determine it.

3rd.—The practical conclusion is that in every structure equipressure must be secured as nearly as possible in order to prevent irregular settlement and consequent cracks.

11. To determine the nature of the settlements that have caused the cracks in existing locks, the plans of a number of them (the histories of which are known) have been examined and the forces at work calculated. The great difficulty with a lock is to determine the amount and the direction of the earth pressure against the walls, such pressure being most uncertain in its action, depending on the nature of the soil, the state of weather, and the way in which the filling has been done. For purposes of calculation the elegant graphic method of Professor Reilly of Cooper's Hill College has been used (communicated by Mr. R. O. Clayton, Assistant Engineer), the natural slope of the earth being taken at 2 to 1.

12. Of all those examined by the writer, the lock that most clearly illustrates the cause of cracks is that at Gowkhally on the Hidgellee Tidal Canal. This was the last lock built on that canal, and the other three having all cracked, extra precautions were adopted in its construction, but without success. The plan and cross sections of the different parts of the lock are shown in figures 2, 3, 4, and 5, from which the method adopted in its construction is seen. All the other locks having apparently cracked from the walls falling back, the backing was done in a novel way calculated in the writer's opinion to directly defeat the object aimed at, which was to secure a constant earth pressure against the walls. The earth backing was carried up in thin layers, very carefully rammed, and a wedge of sand inserted between it and the back of the wall. The lock was commenced in February and finished in the following June, before the rains set in, the foundations being the whole time perfectly free from water; nevertheless the cracks shown on the plan occurred early in June.

13. The figures and arrows on the cross sections show the calculated forces and their directions; in determining the centre of gravity of the walls the sand backing vertically above the footings is considered a part of the wall, the back of which is then assumed to be vertical, and the following units of weight have been adopted—brickwork 112 lbs. per cubic foot, clay backing the same, and sand filling 90 lbs. It is seen that in every case the centre of gravity falls behind the centre of figure of the bearing surface, *viz.*, the point midway between the back of the footings and the centre of the lock, and even the full earth pressure is not sufficient to throw the resultant of the two forces as far forward as this centre point, consequently the pressure on the subjacent earth is greater at the back of the wall than elsewhere. The pressures may be calculated as follows:—

Let x be centre of lock.
y be toe of footings.
P_x = pressure in tons per square foot at x.
P_y = ditto ditto at y.
V_o = distance between intersection of line of pressure with the plane of bearing surface and the centre point of same.
V = half width of bearing surface.
W = area of unit of length of bearing surface.
P = total weight of wall.

R^2 = radius of gyration of bearing surface $= \frac{4\,V^2}{12}$

$$P_x = \frac{P}{W}\left(1 - \frac{V_o V}{r^2}\right)$$

$$P_y = \frac{P}{W}\left(1 + \frac{V_o V}{r^2}\right)$$

14. In table No. 2 are shown the earth pressures calculated as above, both when the weight only is considered to be acting and also when the pressure from backing is taken into account. Then from the pressures so determined, corresponding sinkages are obtained from the former table (the series for foundations 11 feet deep been used), and from these sinkages the widths of the cracks to be expected are calculated and tabulated along with the widths that were actually measured.

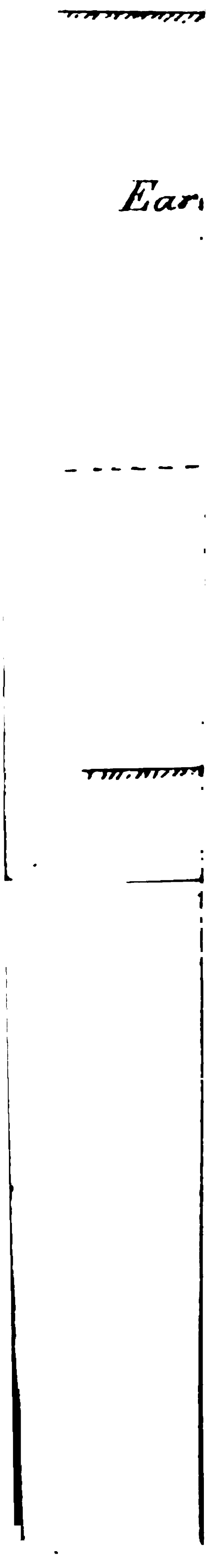
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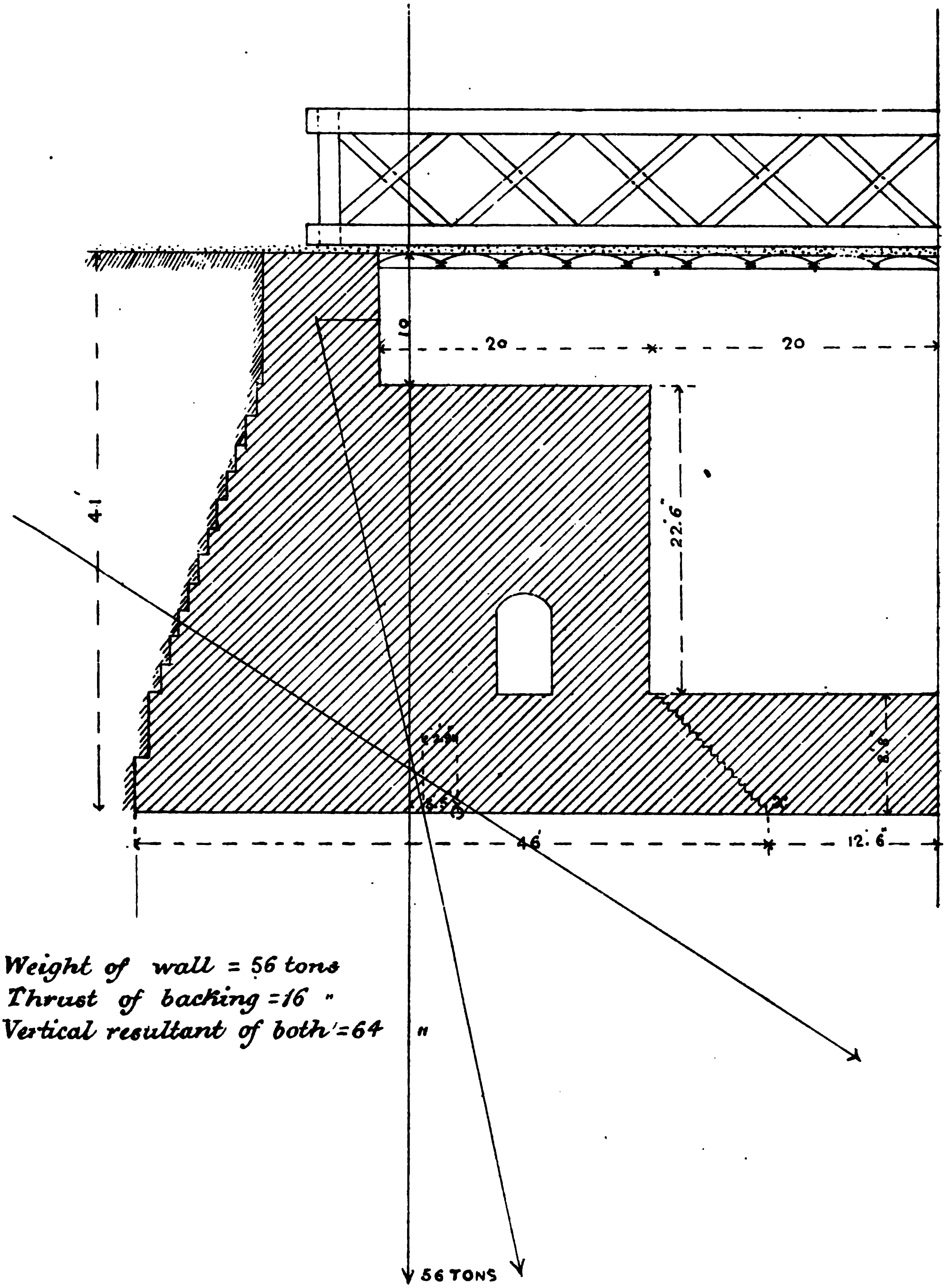
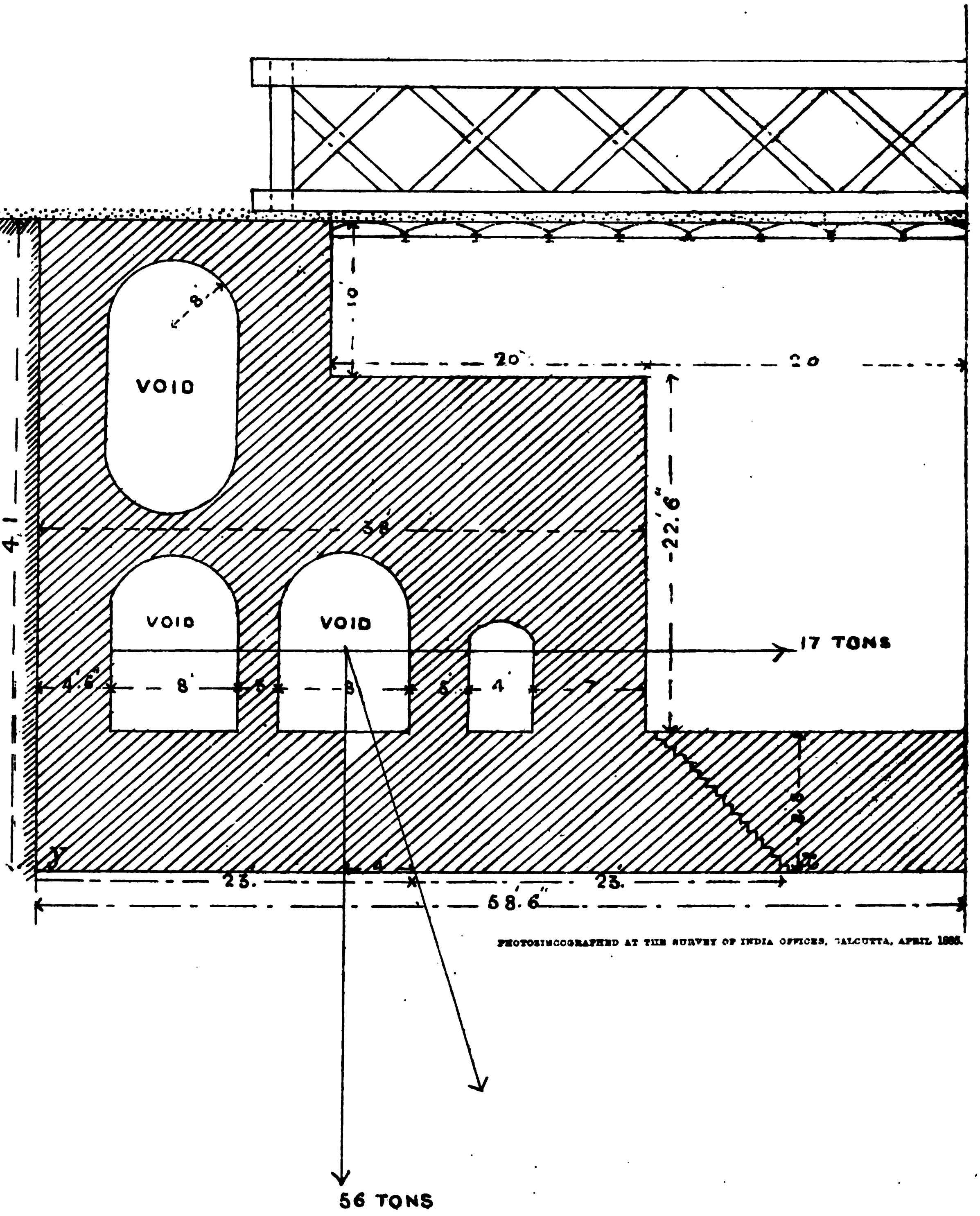
fig. 6



Weight of wall = 56 tons
Thrust of backing = 16 "
Vertical resultant of both = 64 "

fig. 7



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15. Examination of the last three columns of the table will show that for the upper sill and chamber the actual width of cracks falls between those calculated as due to weight only, and those caused by both weight and pressure of backing. This apparently shows that the pressure actually exercised by the backing was considerably less than that calculated, and this is exactly what might be expected from the way that the filling was done. In the case of the lower sill, the crack observed was that due to weight and full earth pressure, but the writer ascribes this to the walls being prevented falling back as much as they otherwise would have done by the support afforded by the wing-walls, which must have given great support prior to the vertical cracks close to their junctions with the lock having occurred. Another explanation that might be given is that there being no invert in this portion of the lock, the flat-floor does not transmit the pressure as far as the centre, and in consequence the centre of the bearing surface is thrown further back, and so more nearly coincides with the resultant of the weight and earth pressure.

16. The width between the walls at coping level has lately been measured by Mr. Norman, Assistant Engineer, at the writer's request, and found to be one inch greater than built between the upper gate counterforts and one and-a-half between the lower; these measurements are about quarter of an inch greater than those due to the widths of the cracks observed, but such a small dimension as quarter of an inch may easily be explained by error in measurement of the width of the cracks, as in the lower sill one quarter inch increase of width at coping level means only one-twentieth of an inch in the crack through sill.

17. All the other locks examined seem to have cracked for the same reason, *viz.*, the settling back of the walls; it is evident, therefore, that when designing a lock, an endeavour should be made to obtain equipressure; but it is not possible to do this with certainty, as the thrust due to the earth backing is subject to variation, and cannot be accurately determined. It would be less injurious to have the resultant fall inside the centre of bearing surface, as then the platform of the lock would be compressed instead of being torn asunder, and it would be capable of resisting to a great extent any tendency of the walls to incline inwards.

18. When the revised design was made for Chitpore lock after it was determined to discard wells, the investigations into the cause of cracks in locks above described had not been made and viewed by the light now thrown on the subject, the necessity of alteration is apparent. Figure 6 shows a cross section through inner bay sill and bridge abutment. The first difficulty that occurs in calculating the earth pressures in a wide lock is to determine the true bearing surface, as the floor 8′ 8″ thick cannot act as footings so far as to the centre line of the lock, a distance of 20 feet. Rankine says that footings transmit pressure to a distance from the toe of the wall equal to their depth, and this seems to be most likely; unless the footings are very weak it certainly is not less, and it cannot well be more, or the pressure would be transmitted through the tenacity of the mortar joints, which is not probable. In calculating the pressure for Chitpore, the bearing surface is therefore taken to extend from y at the back of the wall to x, a distance from the face equal to the thickness of the floor.

19. The total weight bearing on the surface from x to y (figure 6) with a width of one foot neglecting the pressure of the backing, is 56 tons, and the centre of gravity falls 3·5 feet behind the centre of figure; this would give the pressure at x and y as follows :—

$$P_x = 0{\cdot}6 \text{ tons per square foot.}$$
$$P_y = 1{\cdot}8 \quad ,, \quad ,, \quad ,,$$

If the earth pressure be taken into account, the vertical resultant of the weight and pressure will be 64 tons, and will fall 2·75 feet behind the centre of figure, and will therefore give—

$$P_x = 0{\cdot}9 \text{ tons per square foot,}$$
$$P_y = 1{\cdot}9 \quad ,, \quad ,, \quad ,,$$

which would have caused a falling back of the walls of probably one inch.

20. As it was not practically possible to alter the width of the base, the foundations up to sill level having been already laid, there remained no way of forcing the resultant of the weight of the wall, and the pressure of the earth backing to pass through the centre of the bearing surface except to carry up the wall vertically at the back, leaving arched voids in it for lightness. By this means, as shown in figure 7, the resultant has been made to pass through the required point, and if the full pressure expected is given by the earth backing, the pressure from x to y will be equal throughout, and at the rate of 1·2 tons to the square foot. If the full

effect of the backing was not experienced, and the resultant cut the base 2 feet behind the centre, the pressures would be—

$$P_x = 0·9 \text{ tons per square foot.}$$
$$P_y = 1·5 \quad „ \quad „ \quad „$$

If the corresponding sinkages be taken from table No. 1 (last series), the subsidence at *y* would only be ·4″ in excess of that at *x*, or only half as much as would occur under the mostt favourable circumstances as the lock was at first designed. It is very improbable that the earth pressure should fail to bring the resultant within two feet of the centre, especially as the earth will be tipped in behind the walls and let settle of its own accord while exposed to the weather, instead of being carefully rammed in layers which tends much to reduce the thrust. In consequence of the very wide base, the settlement at *y* ·4″ in excess of that at *x*, would only produce a crack of one-eighth of an inch in width. However, even if equipressure be obtained, there will be a settlement of the lock walls according to the table of ·73,″ and although the walls remain plumb, it is probable that there will still be a longitudinal crack through the floor, as it only weighing ·4 of a ton per square foot will sink ·32,″ but being pulled down an extra ·41″ on either side, it will probably have its back broken, but it is quite possible that it might bend to such a very small degree without any visible crack. It is believed by the writer that a longitudinal crack not exceeding one-eighth of an inch in width is the worst that is to be feared.

21. On the above principles the whole of the lock has been so designed as to have equipressure throughout, when the backing is exerting its full thrust; and in the event of its failing to do so, the evil effects will be reduced to a minimum.

TABLE No. 1.

Pressure in tons per superficial foot bearing surface.	FOUNDATIONS TWO FEET DEEP.			FOUNDATIONS FOUR FEET DEEP.			FOUNDATIONS EIGHT FEET DEEP.			FOUNDATIONS ELEVEN FEET DEEP.		
	Observed sinkage in inches.	Calculated sinkage in inches. Ratio of series 1·17.	Increase of sinkage for each extra 0·1 ton pressure.		Ratio 1·15.			Ratio 1·12.			Ratio 1·10.	
0·1		0·03	...		0·02	...		0·008	..		0·23	...
0·2		0·04	0·01		0 03	0·01		0·01	0·002		0·26	0·03
0·3		0·05	0·01		0·04	0·01		0·02	0.01		0·29	0·03
0·4		0 06	0·01		0·05	0·01		0·03	0·01		0·32	0·03
0·5		0·08	0·02		0·06	0·01		0-04	0·01		0·36	0·04
0·6		0·10	0·02		0·07	0·01		0·05	0·01		0·40	0·04
0·7		0·12	0·02		0·09	0·02		0·06	0·01		0·44	0·04
0·8		0·15	0·03		0·11	0·02		0·07	0·01		0·49	0·05
0·9		0·18	0·03		0·12	0·02		0·08	0·01		0 54	0·05
1·0		0·22	...		0·14	...		0·10	...		0·60	...
1·1		0·26	·04		0·16	·02		0·11	·01		0·66	·06
1·2	**0·31**	**0·31**	·05	**0·19**	**0·19**	·03		0·13	·02		0·73	·07
1·3		0·36	·05		0·22	·03		0·15	·02		0·80	·07
1·4		0·42	·06		0·25	·03		0·17	·02		0·87	·07
1·5		0 50	·08		0·29	·04	**0·19**	**0·19**	·02		0·96	·09
1·6		0·59	·09		0·33	·04		0·21	·02	**1·06**	**1·06**	·10
1·7		0·68	·09		0·38	·05		0·24	·03		1·16	·10
1·8		0·81	·13		0·44	·06		0 27	·03		1·27	·11
1·9		0·95	·14		0·51	·07		0·30	·03		1·38	·11
2·0		1·12	·17		0·59	·08		0·34	·04		1·53	·15
2·1		1·31	·19		0·68	·09		0·38	·04		1·68	·15
2·2		1·54	·23		0·78	·10		0·42	·04		1·84	·16
2·3	**2·12**	1·80	·26	**0·90**	**0·90**	·12		0·47	·05		2·02	·18
2·4		**2·12**	·32		1·04	·14		0·52	·05		2 22	·20
2·5		2·50	·38		1·20	·16	**0·69**	0·58	·06		2·44	·22
2·6		2·93	·43		1·38	.18		**0·66**	·08		2·68	·24
2·7		3·44	·51		1·59	·21		0·74	·08	**3·44**	2·92	·24
2·8		4·04	·60		1·84	·25		0·83	·09		**3·21**	·29
2·9		4·75	·71		2·12	·28		0·92	·09		**3 53**	·32
3·0		5·57	·82		2·44	·32		1·03	·11		3·87	·34
3·1		6 55	·98		2·81	·37		1·15	·12		4 26	·39
3·2	**7·69**	**7·69**	1·14	**3·25**	**3·25**	·44		1·28	·13		4·65	·39
3·3		9.02	1·33		3·73	·48		1·43	·15		5·08	·43
3·4		10·60	1·58		4·30	·57		1 61	·18		5·58	·50
3·5		12 45	1·85		4·96	·66	**1·81**	**1·81**	·20		6·13	·55
3·6		14·61	2·16		5·71	·75		2·02	·21		6·70	·57
3·7		17·16	2·55		6 57	·86		2·26	·24	**7·31**	**7·31**	·61
3·8		20·15	2·99		7·59	1·02		2 53	·27		8·00	·69
3·9		23·65	3·50		8·75	1·16		2·83	·30		8·80	·80
4·0		27·78	3·93		10·08	1·33		3·16	·33		9·67	·87

TABLE NO. 2.

POSITION OF CROSS SECTION.	PRESSURE ON SUBJACENT EARTH IN TONS PER SUPERFICIAL FOOT.				CALCULATED SETTLEMENTS IN INCHES.				WIDTH OF CRACKS IN INCHES DUE TO SETTLEMENTS.			REMARKS.
	Due to weight only.		Due to resultant of weight and pressure from earth backing.		Due to weight only.		Due to resultant of weight and pressure from earth backing.		Calculated as due to weight only.	Calculated as due to weight and pressure of backing.	Actually observed.	
	At *x*.	At *y*.	At *x*.	At *y*.	At *x*.	At *y*.	At *x*.	At *y*.				
Through upper sill .	0·7	1·9	1·2	1·5	0·44	1·38	0·73	0·96	1·00	0·26	0·60	On 4th June 1873, Executive Engineer submitted tracing showing cracks to be $\frac{1}{16}$", $\frac{1}{4}$" and $\frac{1}{8}$" wide through upper sill invert and lower sill respectively. On the 17th the Superintending Engineer inspected the lock, and reported that the longitudinal crack had increased in width, being more than half an inch in upper sill; the widths have been increased for all the cracks in the ratio of $\frac{8}{16}$ to $\frac{1}{16}$.
„ chamber .	0·3	1·9	0·7	1·5	0·29	1·38	0·44	0·96	0·50	0·24	0·45	
„ lower sill .	0·0	2·0	0·6	1·4	0·00	1·53	0·40	0·87	0·82	0·23	0·23	

Note on the design of the Coast Canal Locks.

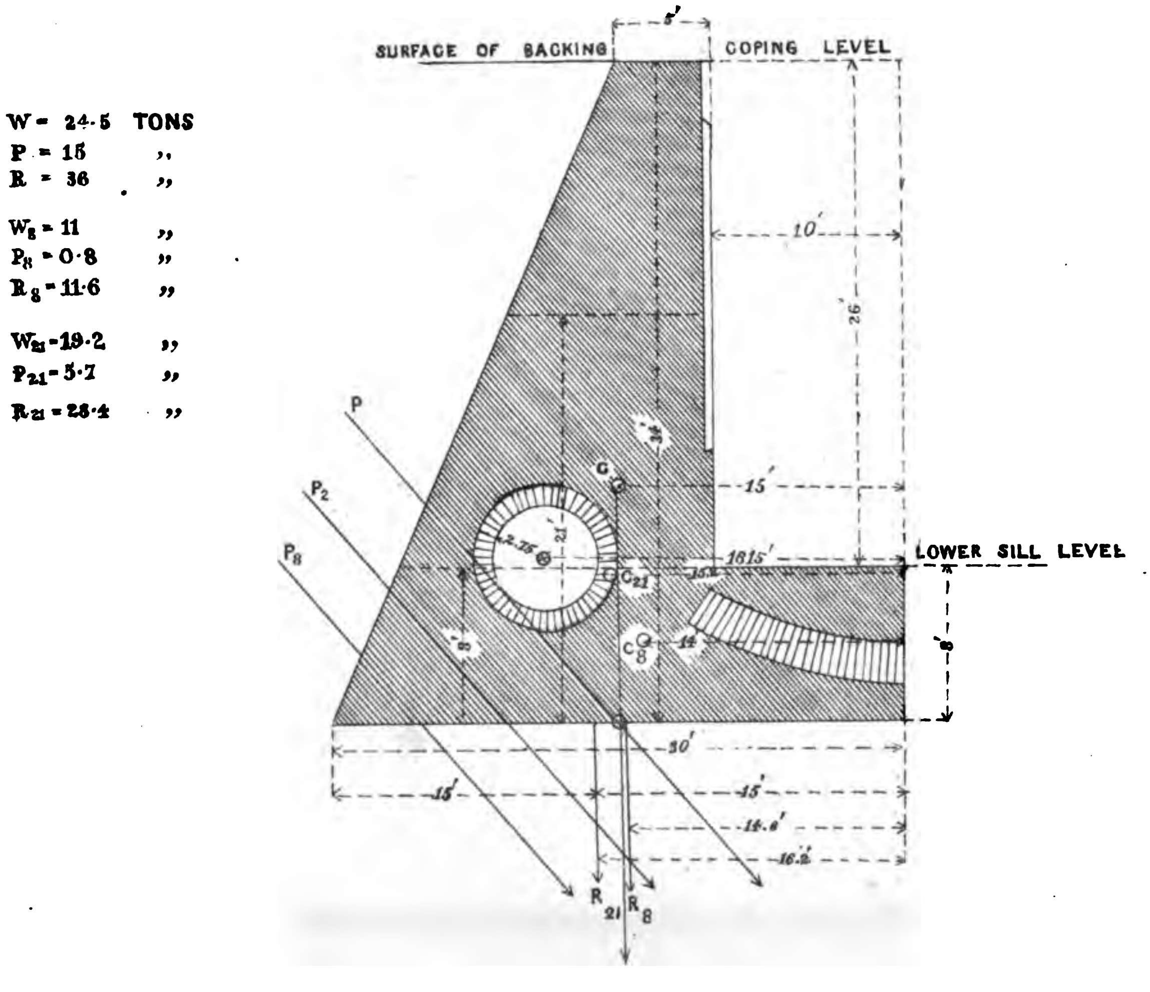
In a previous note on the subject of equalizing pressure on lock foundations it was shewn that the cracks, which have invariably occurred in all locks hitherto built in Bengal, are due to irregular settlement in consequence of the inequality of the pressure on the subjacent earth, due to the resultant of the weight of the lock walls and the pressure against them of the earthen backing not passing through the centre of figure of the foundations. In the following pages the problem is discussed of so designing the coast canal locks as to attain the desideratum of a structure pressing equally on every unit of surface of the earth beneath; if this can be effected, there is every reason to believe that the hitherto inevitable longitudinal crack will be avoided.

2. The eight locks of the coast canal have the following heights from lower sill to coping :—

1 is 27′ 6″.
4 are 26′ 0″.
3 are 22′ 0″.

A perfect cross-section for chamber will first be investigated for a 26 feet high lock—

Fig.1



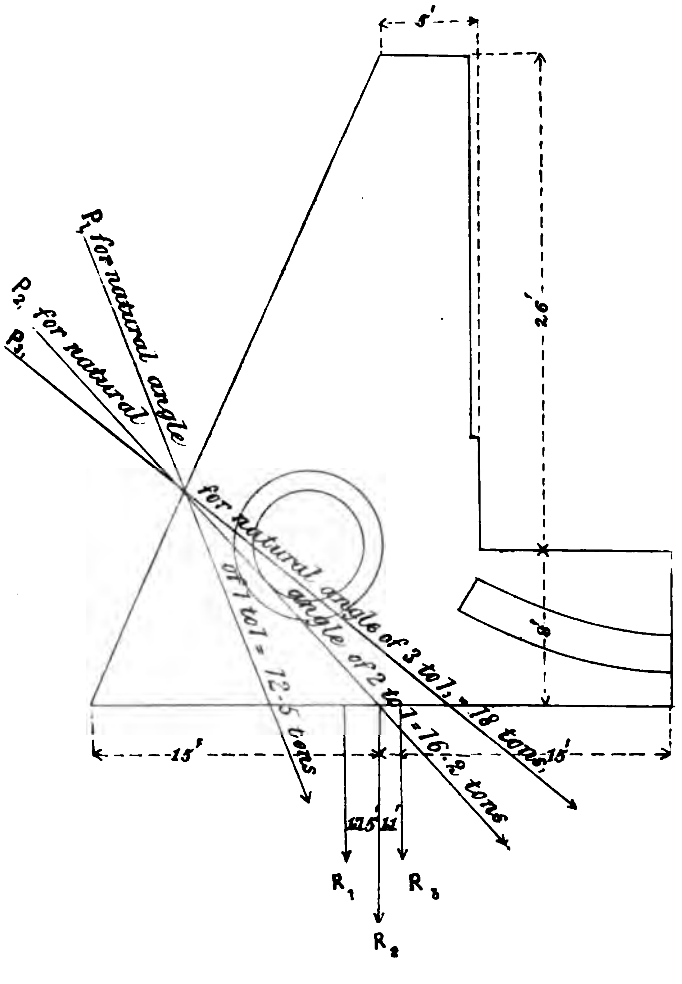
After many trials the cross-section in the above figure 1 has been found to comply with the requirements, as the centre of gravity of the half lock is exactly over the centre point between the middle of the invert and the back of the lock, and also the pressure of the earth backing passes through this point, if the natural slope of the earth is assumed to be 2 to 1, which after due consideration of the nature of the soil in question, and observation for many years past of its behaviour in banks and excavations, seems to the writer to be probably nearest to the truth. (The earth pressure is found by Professor Reilly's graphic method, which, for convenience of reference, is given in an appendix, the weight of a cubic foot of the backing being taken to be 1 cwt., or the same as brickwork.)

NOTE.—In these calculations the locks are considered to have no water in the chamber, as all have cracked hitherto before completion, and in consequence free from water pressure.

3. It is desirable to have such a section that not only will the pressure be equally distributed when the lock is completed, but so that, as it is gradually carried up during construction, the distribution of pressures may not very much vary (most locks have cracked before they were raised to the full height), and inspection of figure 1 will shew that the section adopted fulfils this condition. C is the centre of gravity for the full height, and C_8 and C_2^1 those for heights of 8 feet and 21 feet respectively; the first is exactly over the centre of base, and the other two only depart from the same vertical by distances of 1 and 0·2 feet respectively. If the earth pressure at each height be considered (shewn on figure as P, P_8, P_{21}), and the vertical resultants R, R_8, and R_{21} of each, with the weight of the lock up to the same height be ascertained, it will be found that R_8 and R_{21} only fall 0·4 and 1·2 feet respectively from the centre.

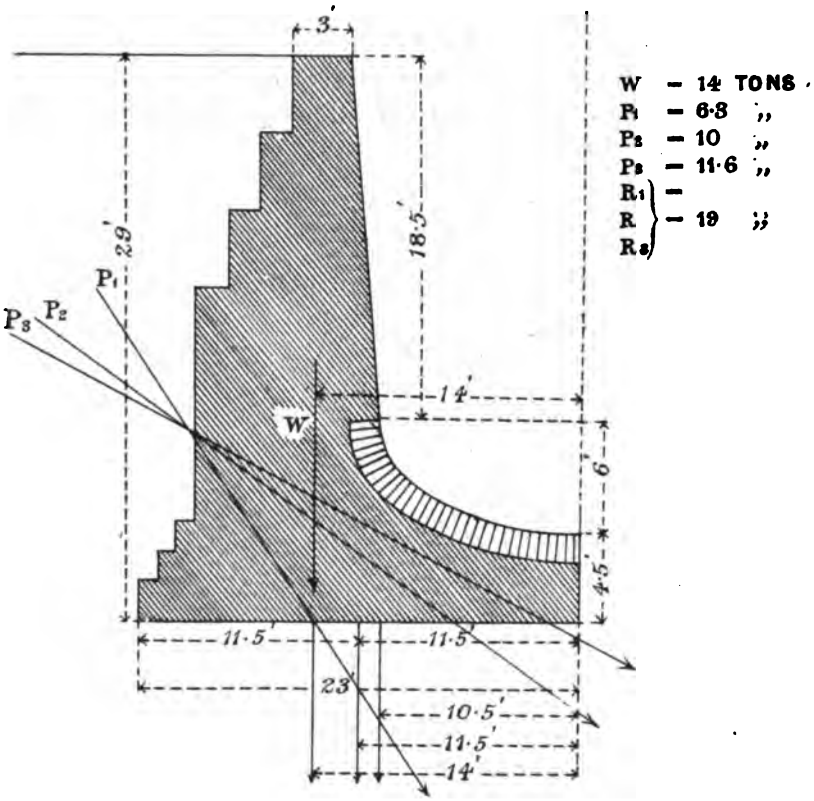
4. It may be said that one of the elements, *viz.*, the earth pressure, is so uncertain that it is useless to make any such calculations, as they may be entirely upset by its variation; but it can be shewn that if the main factor of the pressure, *viz.*, the weight of the lock, be properly disposed, any possible variation in the earth pressure does not so much affect the direction of the resultant—

Fig. 2


5'
26'
8'
P₁ for natural angle of 1 to 1 = 72.5 tons
P₂ for natural angle of 2 to 1 = 76.2 tons
P₃ for natural angle of 3 to 1 = 78 tons
15'
15'
1.75'
1.1'
R₁
R₂
R₃

In figure 2 are shewn the directions and amounts of the earth pressures for the natural angles 1 to 1, 2 to 1 and 3 to 1, the former being the steepest and the latter the flattest slope that can reasonably be supposed to be the true one; and it is found that the vertical resultants R and R_3 of these pressures with the weight depart from the centre by only 1·75 and 1·1 feet respectively, R_2 passing exactly through the centre; these resultants are all equal to 36 tons for each foot in length of the half lock, the greater obliquity of the pressure as the natural slope of earth increases having the effect of keeping the vertical component constant, and the horizontal component is neutralized by the equal and opposite one on the other side of the lock. The pressure due to R_1, R_2 and R_3, on the earth below may now be calculated. As R_2 passes through the centre of the bearing surface the pressure per unit of area will of course be the same all over and equal to $\frac{36}{30}$=1·2 tons; but in the other cases it must be calculated, as was done for Gowkhally lock, on page 3 of first note attached for reference). The results are shewn in the following table, in which they are compared with those calculated in the same way for the chamber wall of the Terapakea lock (figure 3), which, of all the existing locks, the designs of which have been examined by the writer, is the best, as its R_2 passes through the centre of bearing surface :—

Fig. 3



but the direction of the weight falls 2·5 feet behind the centre, and consequently the variation in intensity of pressure on the foundations due to variation of thrust from backing varies much more than in the coast canal design.

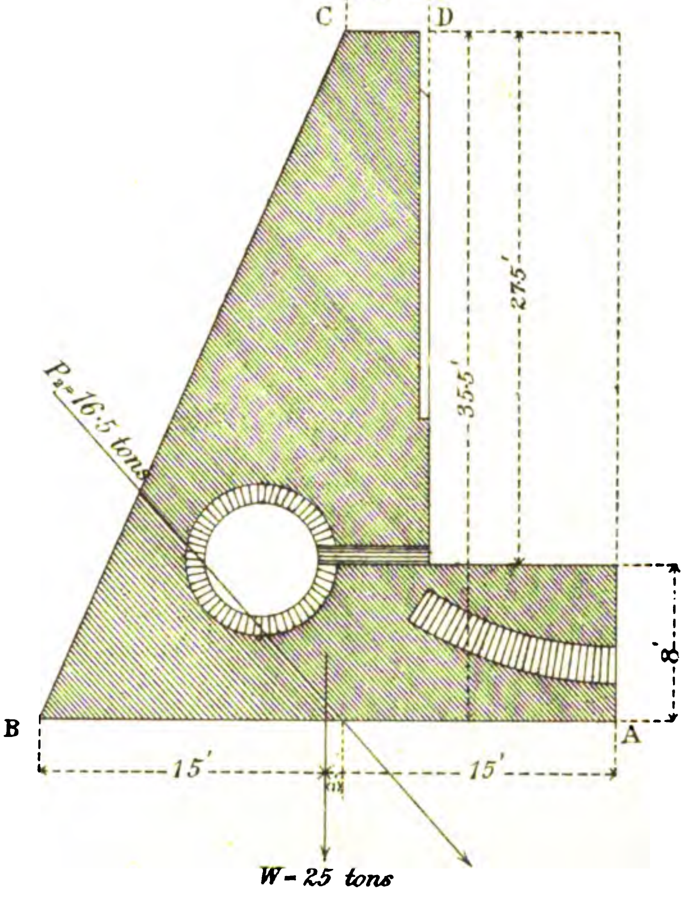
Table comparing the distribution of pressure in Terapakea and Coast Canal Locks.

	Terapakea.		Coast canal lock.	
Height from bottom of foundations to coping . . .	29 feet.		34 feet.	
Half width foundation	21 „		30 „	
Vertical resultant of weight of half lock and pressure of earth backing for a length of one foot	19 tons.		30 tons.	
	At centre of invert.	At rear toe of foundation.	At centre of invert.	At rear toe of foundation.
Pressure in tons per s. ft. on the subjacent earth, when natural slope of backing is taken—				
as 1 to 1	0·31	1·48	0·78	1·62
2 to 1	0·90	0·90	1·20	1·20
3 to 1	1·13	0·66	1·46	0·93
Ratios of the pressures at centre and toe, when the natural slope of backing is 1 to 1 and 3 to 1	1 to 1	3 to 1	1 to 1	3 to 1
	4·8	1·7	2·0	1·5

The ratio between the unit of pressure at centre of invert and toe of foundation, when the natural slope of backing is taken at 1 to 1, being 4·8 for the former and only 2 for the latter lock; when the natural slope of backing is 3 to 1, the ratio for the former is 2 and the latter 1·5; it is thus seen that under possible circumstances the distribution of pressures is nearly two and-a-half times better in the coast canal locks than at Terapakea.

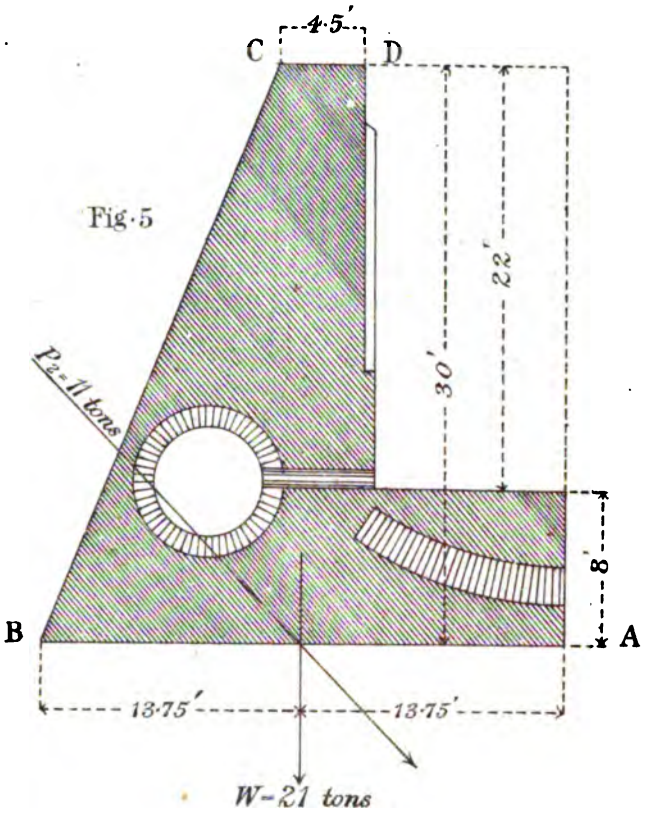
5. For the lock 27·5 feet high from lower sill to coping no alteration is necessary beyond raising the wall the extra 1·5 feet—

Fig. 4



The earth pressure passes one foot on the inside of the centre of base, but this is very inconsiderable in effect, and is on the right side, as excess of pressure towards centre of lock causes the invert and floor to be in compression, which it is enormously better able to resist than tension.

6. The 22 feet high locks have the half width of foundations diminished from 30 to 27·5, the thickness of flooring remaining unchanged; the direction of weight and earth pressure are thus made to pass through the centre of base as shewn in figure 5—



Fig·5

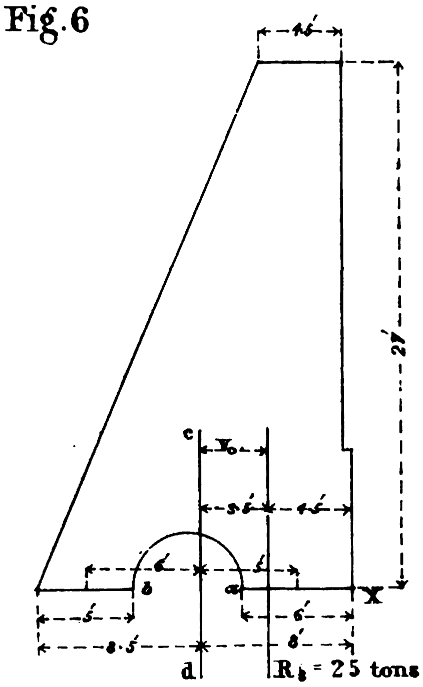
7. Not only has the distribution of pressure in locks hitherto built been bad, but the sections of the chamber, gate, counterforts, and gate recess walls were so different from each other that in the same lock the strains and pressures varied very much in the different parts which must have much tended to irregular settlement; so in the locks now designed the same section has been carried through from end to end, the only departure from it being the inevitable one at the recesses, where the centre of gravity is thrown behind the centre; but this could not possibly be avoided unless by carrying the foundations to a lower level, which would be objectionable in many ways, and the displacement only amounts to ·27 of a foot, the recesses being a comparatively small portion of the whole length of the lock; the very slight tendency to settle back will be resisted by the balanced walls on either side of them, and the excess in the moment of the earth pressure against the back of the valve well, due to it, having a steeper slope than the rest of the lock, tends to counteract the falling back of the recess walls. The invert is carried through from end to end under sills and recess floors, to effect which it is necessary to have it of a greater radius of curvature under the latter than elsewhere. Wing walls have been dispensed with and replaced by cheap revetment; they are useless appendages, give trouble to build, and, in existing locks, seem to have had much to do with the irregular settlement; the lift-locks on the Midnapore Canal are without them, and in consequence have been found more convenient to work than those of the usual type. The other features to note are—firstly, the filling culverts have been carried from end to end of the lock and communicate with the chamber only through 33 small openings on either side, which will ensure the water entering it gently, notwithstanding the very large area (24 s. feet each) of the tunnels; the valves for the filling culverts are similar to those designed for Chitpore lock by the writer, being double faced on rollers fitted with novel starting gear. Secondly, there are reverse gates provided on the riverside so as to prevent high tides and floods entering the canal, and to enable the lock to be worked when the river is higher than the canal, the canal gates are fitted with struts. Thirdly, the gates themselves are of wood, sheeted with Muntz's metal and in place of being framed and planked as usual, the cheap, strong, and enduring American system has been adopted of making them; they will consist of nine-inch beams laid one over the other, bolted together by five vertical rods passing through each beam; thus each beam takes its own pressure and is quite independent of the others. The sills are faced with timber sheeted like the gates and securely bolted down; by this means all need for ashlar in the

sills is avoided. To remove any accumulation of silt that may occur in the recesses of the river-gates a small vent has been provided, passing from inside the filling culvert under the sluice, and escaping just near the heel of the outer gate. Whenever the water in the lock is higher than the river, by closing the riverside culvert valves and opening the small valves of these scouring vents, the accumulated silt will be speedily removed from behind the gates. The entrance channels between the rivers and locks, 150 feet in length, are provided with dwarf walls and floorings, which will much facilitate the keeping of them clear of silt.

8. To shew that sufficient local strength has been provided in all parts of the locks, the following calculations have been made.

Strength of walls to resist earth pressure.—The stress on the face of the wall will evidently be greatest when the earth pressure is a maximum, which is assumed to be when the angle of repose of the backing is taken at 3 to 1; the lock with highest walls will be subjected to the greatest stress, and the weakest part will be on the horizontal line drawn through the centre of filling culvert, because the section of the wall is reduced by the area of the culvert and also in the chamber walls by the small vents communicating with the chamber—

Fig. 6



R_3 is the vertical resultant of the weight of the wall and the earth pressure against it above the line *x y* (fig. 6), and amounts to 26 tons for each foot in length of the wall. The pressure is distributed between the surfaces *y b* and *a x*, and the intensity of it at any point may be found as before: *c d* is the axis of the two surfaces distant from the centre of each inversely as their areas—

V_o = distance between R and *c d* = 3·5
V = 8 for the point *x*
= 8·5 for the point *y*
r^2 = sum of radii of gyration

of *a x* and *b y* round *c d*, which is equal to the sum of their radii of gyration round their own axis and the squares of the distances of these axes from the common axis *c d*—

P_x = pressure in tons per s. ft. at *x*
P_y = „ „ „ „ „ *y*

$$P_x = \frac{25}{11}\left(1 + \frac{V_o V}{r^2}\right)$$

$$V_o = 3{\cdot}5$$

$$V = 8$$

$$r^2 = \left(\frac{6 \times 6}{12} \times 5_2\right) + \left(\frac{5 \times 5}{12} + 6^2\right)$$

$$= 66$$

$$P. = 2{\cdot}3\left(1 + \frac{3{\cdot}5 \times 8}{66}\right)$$

$$= 2{\cdot}3 \times 1{\cdot}42 = 3{\cdot}26$$

52lbs. per s. inch.

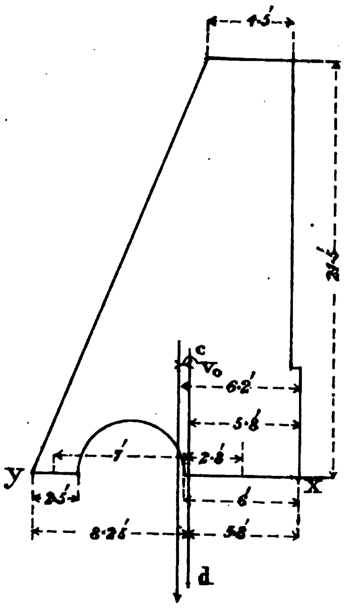
In consequence of the reduction of section on the face of the chamber wall by the small vents one foot in diameter, the intensity of the stress will be increased in the ratio of 7 to 5 or to 73lbs. per s. inch—

$$P_r = 2{\cdot}3\left(1 - \frac{3{\cdot}5 \times 8{\cdot}5}{66}\right)$$
$$= 2{\cdot}3 \times {\cdot}55 = 1{\cdot}26$$
$$= 20\text{lbs. per s. inch.}$$

It is thus seen that the maximum stresses are a mere fraction of what the most ordinary brickwork would safely bear. Were it not for the filling culvert, the back of the wall at *y* would be liable to a tensional stress of 24lbs. to the s. inch, so the apparent paradox occurs of a wall being strengthened by a reduction of its section.

9. In the case of the 22 feet high lock (fig. 7) the filling culvert—

Fig. 7



vent is placed so near to the back of the wall that it looks rather weak at that point, so the maximum stress had better be calculated. It is evident that the less the thrust of the backing is the greater will be the stress on the back of the wall, as R will fall nearer to it; the vertical resultant R of the weight and the earth thrust for a natural angle of 1 to 1 is taken and found to amount to 13 tons, and to cut the base 6·2 feet from the face of the wall. Calculating as above, the following values will be found:—

$$P_s = 16\text{lbs. per s. inch.}$$
$$P_r = 15\text{lbs. ,, ,,}$$

so the effect of the tunnel being so near the back of the wall is only to equalize the pressure. Besides that, compounded of the weight of the wall and the pressure of the backing, there is no other stress to which this thin part is exposed, because it would not be possible even to subject it to a head of water as there is free ventage into the chamber through the small openings; but suppose these to be stopped, and the maximum head that any of the locks are liable to, *viz.*, 14 feet, to be acting to burst the tunnel, the stress on each unit may be calculated as follows:—

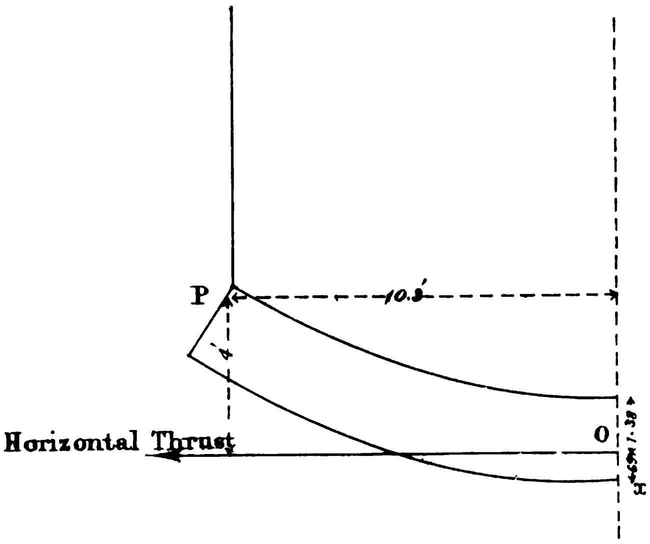
The pressure exerted by a head of 14 feet on 1 s. foot will be 14×62·25 = 871lbs., but the perimeter of a circle whose area is 1 s. foot = 3·54, which, multiplied by the thickness, 2·5, will give 8·8 s. feet, or 1,267 s. inches on the area which would have to be fractured; but the pressure is only 871 lbs., or less than three-fourths of a lb. to the s. inch. It is thus shown that there is an enormous surplus of strength with the tunnel where it is, and to bring it nearer to the face would make the valve well too close to the gates.

10. As the invert distributes the pressure, it is necessary to see that it is strong enough for the purpose; so the maximum stress on the brickwork of the ring may be calculated as follows:—

The stress will evidently be a maximum when the thrust of the earth backing is a maximum, and the pressure is consequently greater in the centre of the invert than at the toe of the foundations. From the table in paragraph 4 it is seen that for the 26 feet high lock under the above circumstance, the pressure at centre is 1·46 tons per s. foot at the centre, and 0·93 at the rear toe; therefore for each foot from the toe to the centre it increases at the rate of

$$\frac{1{\cdot}46 - 0{\cdot}93}{30} = 0{\cdot}018.$$

Fig. 8



Now, if the line of least resistance pass through O, one-third of the thickness of the invert from the extrados, and through P, one-third of the thickness from the springing, it is evident that the horizontal thrust at centre will be a maximum, and its moment round P will be equal to the sum of the moments of the upward pressures round the same point; but the sum of these moments

$$= \frac{K x^2}{2} + \frac{a x^3}{3}$$

When K = pressure upwards through P.
A = unit of increase of pressure as centre of invert is approached.
X = horizontal distance from P to O.

In the present instance—

K = 1·25 tons per s. foot.
A = 0·018 „ „ „
X = 10·3 feet.

Sum of moments round P—

$$= \frac{1{\cdot}25 \times 10{\cdot}3^2}{2} + \frac{0{\cdot}018 \times 10{\cdot}3^3}{3}$$

$$= {\cdot}73 = H\ T \times 4$$

Horizontal thrust at crown = 18·25 tons.

If it passed half-way between the intrades and extrades, the arch being 2·08 feet thick, the stress in tons per s. foot would be—

$$\frac{18{\cdot}25}{2{\cdot}08} = 140 \text{ ibs. per s. inch};$$

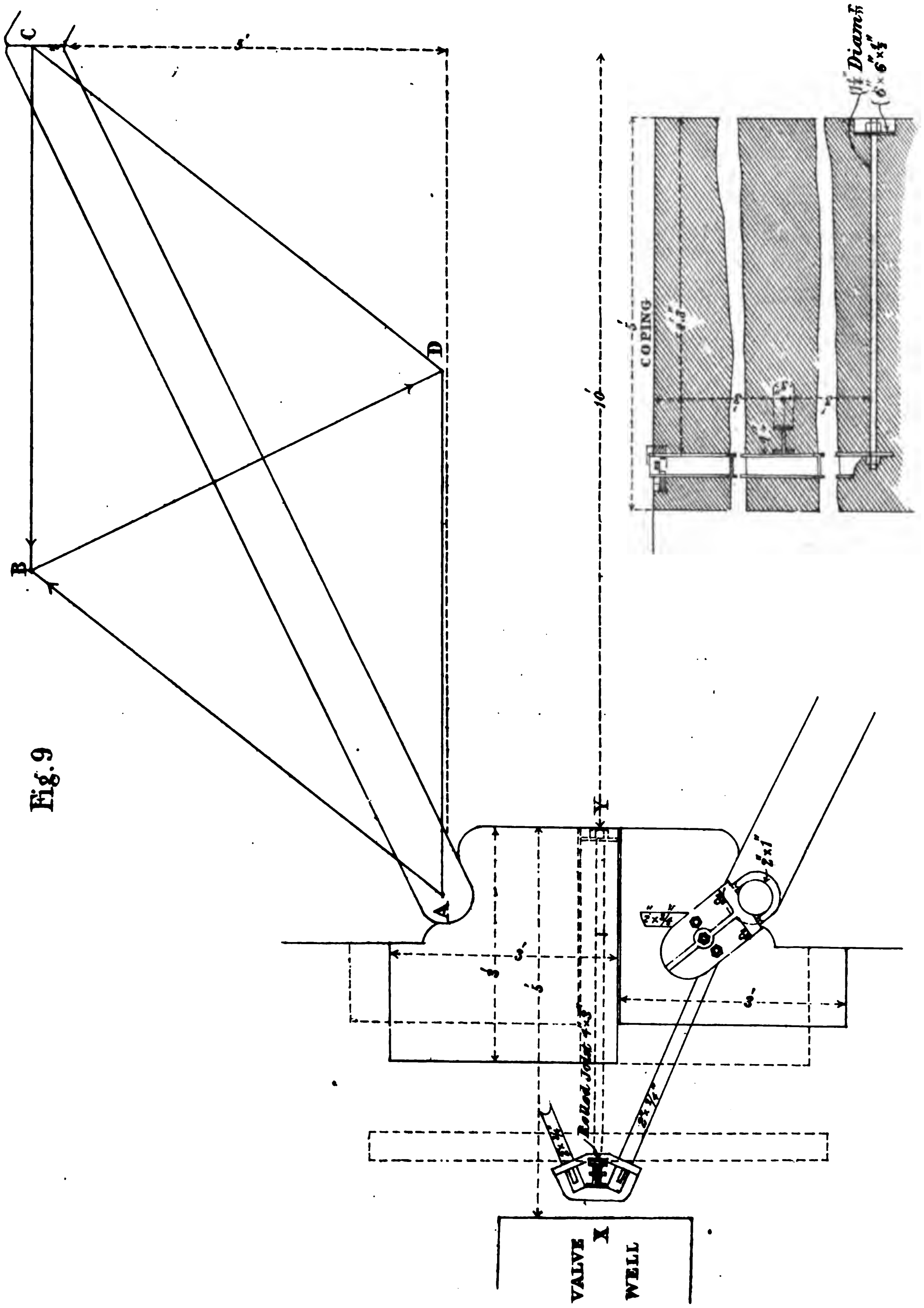
but it may pass possibly only one-third of the thickness from the extrados; this will be doubled, and the maximum stress will become 280lbs. per s. inch.

This is undoubtedly a high pressure, but not more than a really well-built invert should be able to withstand, and it is proposed to use some Portland cement in the mortar and to bond the whole invert together, not building it in separate half-brick rings as is generally done.

11. The only calculations now remaining to be made are those concerning the lock gates.

The rise of the sill is made one-fourth the width of the lock in the clear—

Fig. 9



VERTICAL SECTION ON XY.

From the parallelogram of forces, A, B, C, D (fig. 9), it is evident that the reactions through the miter force and heel-post are in equilibrio with the water pressure against the gate, and it is easy to ascertain by scale that each of the former is to the latter in the ratio of 63 to 59, so the latter being calculated their value can at once be ascertained. The pressure B D of the water produces two effects on the gate, *viz.*, a bending moment round the centre and compression along the line A C. In an iron gate it is necessary to take the latter into consideration, but in a solid wooden one it is so insignificant compared to the section that it may be neglected, and only the effects of the bending moment considered. The greatest head that any of the locks could be subjected to would be in the case of the outer gates of Baintghur lock, which, at dead low water of spring-tides, might have 18 feet of water against them on the inside and only 3 feet outside, which would produce a pressure on each of the three lower beams of the gate of—

$$\frac{11{\cdot}5\times15\times62{\cdot}25}{112}\qquad 95\text{ cwt.}$$

11·5 = unsupported width of gate.
15 = head of water, being difference inside and outside gates.

The necessary thickness may be found by the common formula—

$$W=\frac{BD^2}{S}\times K.$$

When B = breadth of beam in inches 12
D = thickness to be determined
S = span in feet
W = breaking weight in cwt. at centre, which should be taken at ten times the load to be resisted, or five times the distribute load, or 475 cwt.
K = ·7 per teak wood
D = 7·9 inches

but a thickness of nine inches has been allowed, which gives a strength 30 per cent. greater than required. The thrust against the hollow quoins will, for a depth of 18 feet of water against the gates (the slight counteracting effect of three feet of water on the sill is omitted to shorten calculations), be—

$$\frac{11{\cdot}5\times18\times9}{36}\times\frac{63}{59}=55\text{ tons,}$$

which acts one-third of the height, *viz.*, six feet from the bottom; so the overturning moment will be 330 foot-tons, but the moment of stability of the lock along the line of thurst is not less than 3,000 foot-tons if the thurst be supposed to be resisted by a slice four feet wide, that being about the width that the quoin stones would distribute it over without taking into account the cohesion of the brickwork. The weight of the gates for the 27·5 feet lock is about six tons each, so when hanging in air the pull on the collar-strap will be—

$$29\,T=6\times6$$
$$T=1{\cdot}25\text{ tons.}$$

29 being the height from pintle to collar, and six the half width from centre of pintle to mitre-post. T is of course independent of the height of the gate, and will be the same for all the locks whatever their height may be. For the two lower gates, the pull from which converges to the same point when the gates are closed, the anchor gear must be made to resist 2·5 tons, and the width between the coping and the valve well being only five feet, a little care is necessary to obtain a secure hold for the anchor gear. The usual system of trusting to holding-down bolts for securing the anchor straps is not very good, as the whole stress is thrown on the upper layer of brickwork, and, as the gates are usually hung while the work is green, it is quite possible to have a failure unless a very great margin of safety be allowed. To obviate all danger, the gear shewn in figure 9 has been devised, which prevents the possibility of any yielding without motion of a mass of brickwork and hollow quoins 24 s. feet in area and 6 feet deep, weighing at least seven tons. The anchor straps are cottered into a casting which fits into the top of a rolled iron joist built into the brickwork whose lower end is bolted right through to the face, and which iscrossed in the middle by another joist of the same dimensions, also built in. This arrangement, though apparently elaborate as seen in the plan, is really simpler and cheaper than that usually adopted. It is proposed to open and shut the gates by the simple rack and pinion gear in use on the Sone canals.

Appendix to Note on Coast Canal Locks.

Professor Reilly's graphic method of ascertaining the earth pressure against a retaining wall—

Fig. 1

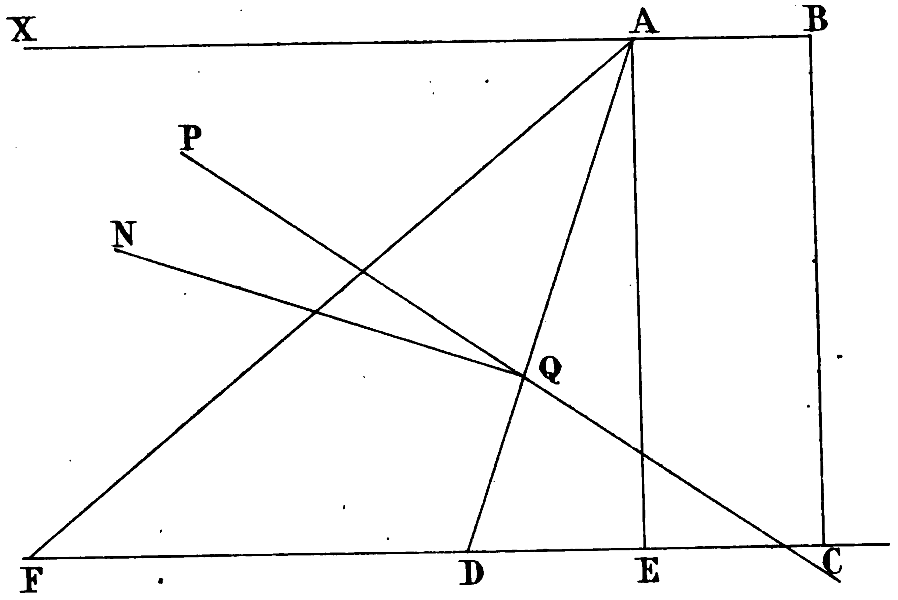
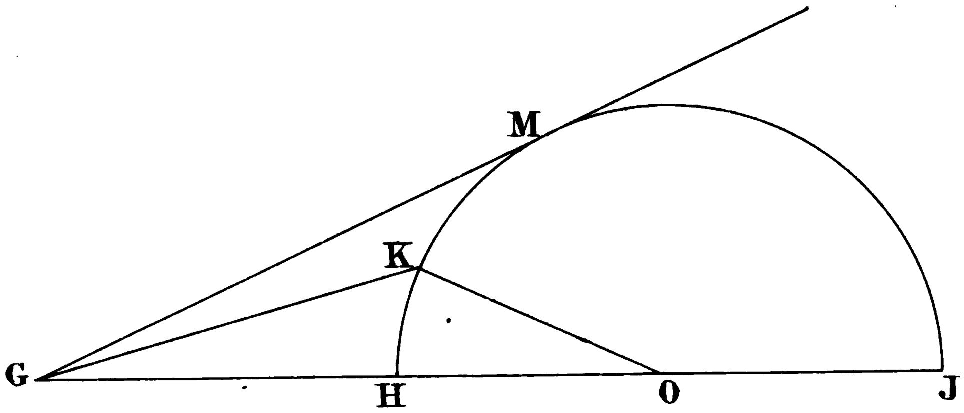


Fig. 2



Let A B C D (fig. 1) be the retaining wall; draw J G M (fig. 2) equal to the angle of repose of the earth; describe a semi-circle on G J, touching G M; make the angle K O G equal to twice the angle D A E, which the back of the retaining wall makes with a vertical. Then the angle K G O will be equal to the angle P Q N, which the direction of the resultant earth pressure will make with the normal N Q to the back of the wall, at the point Q, a third of the height from the bottom.

Make F D : A E::G K : G J. The triangle A D F will, represent the pressure, or, in other words—

$$P = \frac{h^2}{2} \times \frac{GK}{GJ}$$

when h = vertical height of wall.

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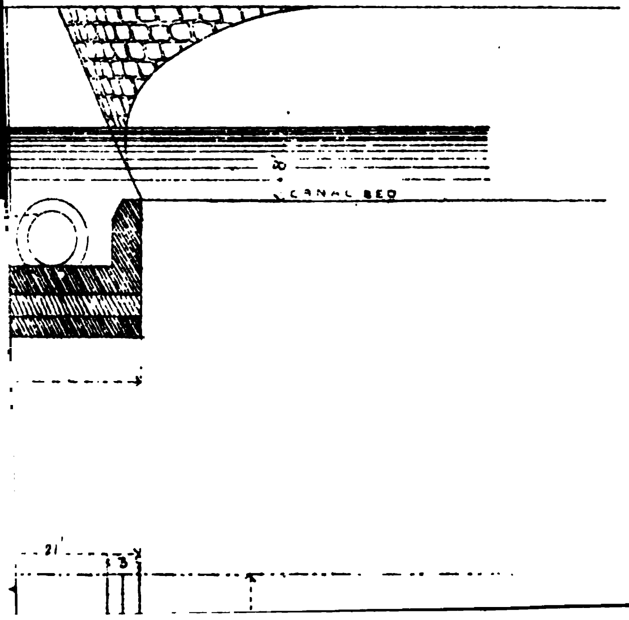
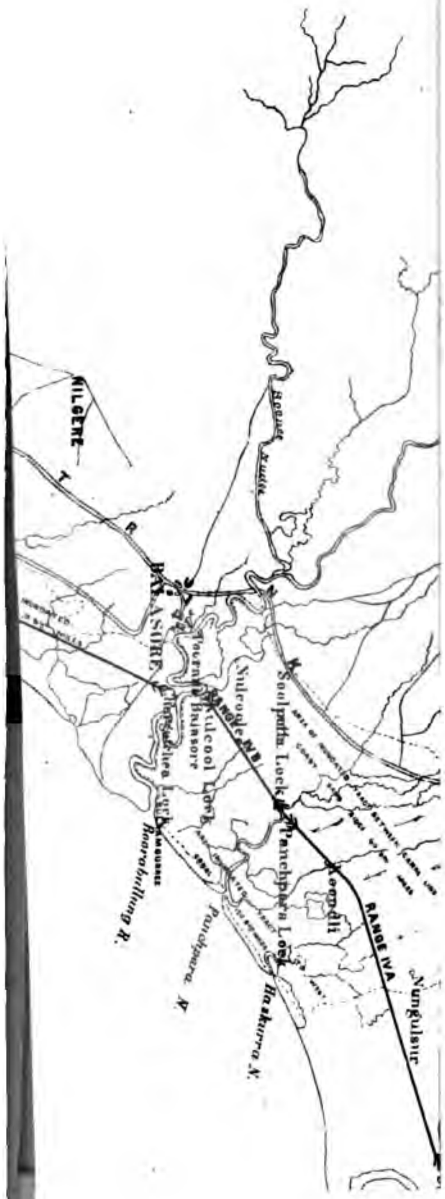


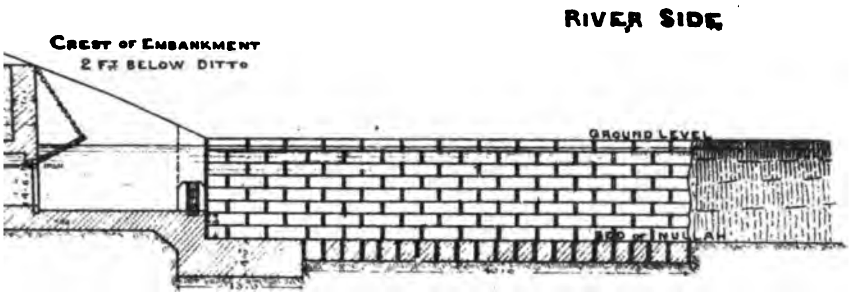
CANAL BED


NILGERE
BALASORE
Tournia Bhinsore
Sulcoole
Sulcool Lock
Soolpatta Lock
Panchpara Lock
RANGE IV B
RANGE IV A
Nungulsur
Boorabullung R.
Panchpara N.
Baskurra N.

SUPPLY SLUICE

River Side Flap Shutter chained up during season that sluice supplies Canal, and Canal Side Shutter during Drainage Season

ION on A.B.



ABOVE SILL